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(54) Process for producing a leather-like sheet

(57) A fibrous substrate, in particular a fibrous substrate comprising a microfibrillar fiber-forming fiber is impregnated with a composite resin emulsion obtained by emulsion-polymerizing an ethylenically unsaturated monomer (B) in the presence of a polyurethane-based emulsion (A) at a weight ratio of the (A) / the (B) of 90/10 to 10/90, the emulsion having heat-sensible gelatinizing ability making it possible to supply a film having a specific elastic modulus. Subsequently, the emulsion is gelatinized. In the case that the fibrous substrate is a microfibrillar fiber-forming fiber, this fiber is converted into a microfibrillar fiber bundle. In this way, a leather-like sheet is produced. This process makes it possible to obtain a leather-like sheet having excellent softness and fulfillment feeling, and good hand touch, feel and physical properties like natural leather. In the case that the fibrous substrate particularly comprises a microfibrillar fiber, it is possible to obtain a leather-like sheet having the above-mentioned characteristics and suede-like high-quality.

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## Description

[0001] The present invention relates to a process for producing a leather-like sheet, and a leather-like sheet obtained by the process. More specifically, the present invention relates to a process for producing a leather-like sheet wherein a fibrous substrate comprising an ordinary fiber or a microfine fiber is impregnated with a specific composite resin emulsion and then the emulsion is solidified, and a leather-like sheet obtained by this process. The leather-like sheet obtained by the present invention has far more satisfactory softness and fulfillment feeling than conventional leather-like sheets obtained by impregnating a fibrous substrate with an emulsion type resin and then thermally-drying and solidifying the resin, and has excellent and high-grade hand touch and feel like a natural leather and satisfactory

[0002] Hitherto, sheets wherein a fibrous substrate is impregnated with a resin component, such as polyurethane, as a binder have been produced as substitutes (artificial leather) for natural leathers. A typical producing process thereof includes the following: a so-called wet process of impregnating a fibrous substrate with a solution in which a resin component, a typical example of which is polyurethane, is dissolved in an organic solvent such as dimethylformamide, and then immersing the resultant in a non-solvent such as water to solidify the resin component; and a so-called dry process of impregnating a fibrous substrate with a solution in which a resin component is dissolved in an organic solvent or an emulsion in which the resin component is dispersed in water, and then drying the resultant to solidify the resin component.

[0003] The wet process makes it possible to obtain a sheet having hand touch nearer to natural leather than the dry process, but is poor in productivity. The wet process also has a problem that it is indispensable to use the organic solvent harmful to the human body, such as dimethylformamide. On the other hand, in the case that the resin emulsion is used in the dry process, a sheet can be obtained without use of any organic solvent. However, the hand touch of the sheet is far poorer than that of the sheet obtained by the wet process. This is because in the sheet obtained by the dry process the resin locally shifts in the fibrous substrate in the drying step thereof to produce a structural form wherein fibers are strongly restrained in the local portion, thereby causing the softness of the sheet to be lost and making its hand touch hard. If the adhesion amount of the resin is made small not to damage the flexibility, the hand touch of the fibrous substrate, such as a nonwoven fabric, is exhibited as it is. Thus, leather-like hand touch cannot be obtained. On the other hand, if the adhesion amount of the resin is made large to obtain fulfillment feeling and leather-like hand touch, the softness drops so that the sheet gets hard. In either case, it is impossible to obtain high-grade hand touch like natural leather. This is true not only in the dry process using any resin emulsion but also in the dry process using any organic solvent solution of the resin.

[0004] It may be thought out that in the dry process the resin is added and subsequently a softener is also added to exhibit softness. However, addition of the step of adding the softener is necessary so that productivity drops. Furthermore, even if the softener is added, it is difficult to obtain high-grade hand touch like natural leather.

[0005] Specific examples of suggested methods using an emulsion resin include a method of impregnating a fabric with a mixed resin emulsion of a polyurethane emulsion and a polyacrylic ester emulsion and then treating the resultant with hot water to produce a base fabric for artificial leather (JP-A-128078/1980);

and a method of adding an emulsion solution wherein inorganic salts are dissolved in an aqueous polyurethane emulsion having an average particle size of 0.1 to 2.0  $\mu\text{m}$  to a nonwoven fabric sheet comprising a fiber layer made mainly of a microfine fiber having a monofilament fineness of 0.5 denier or less, and then drying the resultant by heating to produce an artificial leather (JP-A-316877/1994). It is difficult to say that the artificial leathers obtained by these methods have sufficiently improved softness and hand touch.

[0006] For the above-mentioned reasons, at present the wet process is exclusively adopted in the industry for producing artificial leather, the wet process being capable of obtaining high-quality artificial leather but being low in productivity and indispensable to use an organic solvent.

[0007] However, in the process for producing a leather-like sheet wherein a fibrous substrate is impregnated with an aqueous resin emulsion and then the resin is heated and solidified, the typical example of which is the above-mentioned dry process, it is unnecessary to use any organic solvent upon the impregnation of the fibrous substrate with the resin or solidification of the added resin. Therefore, such a process is very effective from the standpoint of environment adaptability, safety of working environment and simplicity of the process. For this reason, there has been strongly demanded development in a technique for producing a leather-like sheet that is satisfactorily soft and dense and has high quality, using the aqueous resin emulsion.

[0008] The sheet whose fibrous substrate is composed of a microfine fiber has good hand touch like natural leather and is used as a so-called high-class suede-like artificial leather. Typical examples of the producing process thereof include the method (1) of impregnating a fibrous substrate comprising a microfine fiber-forming composite spun fiber or blend spun fiber of a sea/island type with an organic solvent solution of a resin, wet-solidifying the resin, dissolv-



ing/removing or decomposing/removing the sea component with an organic solvent or an alkali solution to leave the island component as a microfibrillar fiber, thereby turning the fiber which makes the fibrous substrate into the microfibrillar fiber, and the method (2) of forming beforehand a substrate comprising a microfibrillar fiber which has already been produced, impregnating the substrate with an organic solvent solution of a resin, and wet-solidifying the resultant. However, such methods also have the above-mentioned problems. If the adhesion amount of the resin is made small not to make hand touch hard, there remains a problem that the resultant sheet has hand touch like a fibrous substrate that is not dense

[0009] In the light of the above-mentioned background, there has been strongly demanded development in a technique using an aqueous resin emulsion superior in environment adaptability, safety of working environment, and simplicity of the producing process, the technique being also capable of being applied to a fibrous substrate comprising a microfibrillar fiber and capable of supplying a high-quality leather-like sheet having excellent softness and fulfillment feeling.

[0010] An object of the present invention is to provide a process for producing a leather-like sheet that is excellent in softness and fulfillment feeling, and has good hand touch, feel and physical properties like natural leather and high quality like suede, using a specific resin emulsion; and a leather-like sheet obtained by this process.

[0011] In order to attain the above-mentioned object, the inventors made various investigations, and have found the fact that if a specific composite resin emulsion having a heat-sensible gelatinizing ability is used as a resin emulsion to impregnate a fibrous substrate with this emulsion and gelatinize the emulsion, the composite resin is solidified without restraining any fiber and is filled into fiber spaces. The inventors also have found that this fact makes it possible to supply a leather-like sheet that is excellent in softness and fulfillment feeling, and has very good hand touch, feel and physical properties like natural leather and high quality. Thus, the present invention has been made.

[0012] Furthermore, the inventors have found that if the fibrous substrate comprising a microfibrillar fiber-forming fiber is impregnated with an emulsion of a composite resin having a heat-sensible gelatinizing ability and specific physical properties and then the emulsion is solidified followed by converting the microfibrillar fiber-forming fiber into microfibrillar fiber, it is possible to obtain a leather-like sheet that is highly soft and dense and has physical properties like natural leather and high quality equal to that of sheet obtained by the wet process. That is, the inventors have found that by using the specific heat-sensible gelatinizing emulsion and converting, after the addition of the resin, the microfibrillar fiber-forming fiber of the fibrous substrate into a microfibrillar fiber, the fibrous substrate is impregnated with the resin in the state that the resin does not restrain the microfibrillar fiber inside the substrate to keep appropriate fiber spaces, and subsequently the resin is solidified to supply a leather-like sheet that is highly soft and dense and has high quality. As a result, the present invention has been made.

[0013] That is, the present invention is a process for producing a leather-like sheet, comprising the step of impregnating a fibrous substrate with a composite resin emulsion having the following requirements (i)-(iv), solidifying the emulsion, and then performing the step (v):

- (i) the requirement that the composite resin emulsion has heat-sensible gelatinizing ability,
- (ii) the requirement that a film of 100  $\mu\text{m}$  in thickness, obtained by drying the composite resin emulsion at 50°C, has an elastic modulus at 90°C of  $5.0 \times 10^8 \text{ dyn/cm}^2$  or less, and in the case that the fiber which makes the fibrous substrate is not any microfibrillar fiber-forming fiber, the elastic modulus is  $1.0 \times 10^7 \text{ dyn/cm}^2$  or more,
- (iii) the requirement that in the case that the fiber which makes the fibrous substrate is a microfibrillar fiber-forming fiber, the film of 100  $\mu\text{m}$  in thickness, obtained by drying the composite resin emulsion at 50°C, has an elastic modulus at 160°C of  $5.0 \times 10^6 \text{ dyn/cm}^2$  or more,
- (iv) the requirement that the composite resin emulsion is an emulsion that can be obtained by emulsion-polymerizing an ethylenically unsaturated monomer (B) in the presence of a polyurethane-based emulsion (A) in the manner that a weight ratio of polyurethane in the component (A) to the component (B) is from 90/10 to 10/90, and
- (v) in the case that the fibrous substrate is the microfibrillar fiber-forming fiber, subsequently converting the microfibrillar fiber-forming fiber into a microfibrillar fiber bundle.

[0014] A preferred process for producing such a composite resin emulsion is comprising emulsion-polymerizing an ethylenically unsaturated monomer (B) in the presence of a polyurethane-based emulsion (A), wherein a polyurethane-based emulsion satisfying the following requirements ①-③ is used as the polyurethane-based emulsion (A):

- ① the requirement that the polyurethane-based emulsion is a polyurethane-based emulsion prepared by reacting an isocyanate-terminal urethane prepolymer with a chain extender in the presence of a surfactant in an aqueous solution,
- ② the requirement that the polyurethane-based emulsion is a polyurethane-based emulsion having, in its polyurethane skeleton, from 5 to 25 mmol of neutralized carboxylic groups and/or sulfonic group per 100 g of the polyurethane, and



③ the requirement that the polyurethane-based emulsion is a polyurethane-based emulsion having from 0.5 to 6 g of the surfactant per 100 g of the polyurethane.

[0015] The present invention will be described in detail hereinafter.

[0016] First, the fibrous substrate used in the present invention will be described. This fibrous substrate is any fibrous substrate having appropriate thickness and fulfillment feeling and having soft hand touch, and may be any one selected from fibrous substrates, such as a nonwoven fabric and a woven/knitted fabric, which has been conventionally used in the process for producing leather-like sheets. Above all, in the present invention, preferable are a fibrous substrate made only of a nonwoven fabric, and a multi-layer product which is made of a nonwoven fabric and a woven fabric and/or a knitted fabric and which has, at the side of at least one surface, a layer of the nonwoven fabric (for example, a two-layer structure composed of a nonwoven fabric layer and a knitted/woven fabric, and a three-layer structure composed of a knitted/woven fabric sandwiched between nonwoven fabrics). More preferable is a fibrous substrate made only of a nonwoven fabric. The nonwoven fabric preferably used as the fibrous substrate may be a fiber-entangled nonwoven fabric or a lap type nonwoven fabric. Above all, a fiber-entangled nonwoven fabric is preferable.

[0017] Examples of the fiber which makes the fibrous substrate include synthetic fibers such as polyester-based, polyamide-based, acryl-based, polyolefin-based, polyvinyl chloride-based, polyvinylidene chloride-based, and polyvinyl alcohol-based fibers; and natural fibers such as cotton, wool and hemp. Above all, preferable are fiber substrates made mainly of synthetic fibers such as polyester-based, polyamide-based and acryl-based fibers.

[0018] The above-mentioned fiber which makes the fibrous substrate may be any one selected from ordinary fibers, which do not cause shrinkage or extension, shrinkable fibers, potentially spontaneously-extendable fibers, various composite fibers (for example, multilayer-laminating type potentially separable composite fibers), blend spun fibers, micro-fine fibers, fibers in the form of a bundle thereof and special porous fibers.

[0019] The thickness of the fiber which makes the fibrous substrate is not especially limited and may be selected in accordance with uses of the resultant leather-like sheet. In general, the monofilament fineness of the fiber is preferably within the range of 0.01 to 10 deniers and more preferably within the range of 0.02 to 8 deniers.

[0020] The thickness of the fibrous substrate is not especially limited and may be selected in accordance with uses of the resultant leather-like sheet. From the viewpoint of hand touch, the thickness is preferably within the range of 0.3 to 3.0 mm and more preferably within the range of 0.8 to 2.5 mm.

[0021] The apparent density of the fibrous substrate is preferably within the range of 0.1 to 0.5 g/cm<sup>3</sup> and more preferably within the range of 0.15 to 0.45 g/cm<sup>3</sup> because it is possible to obtain a leather-like sheet having soft hand touch, appropriate firmness-feeling and repellency. If the apparent density of the fibrous substrate is less than 0.1 g/cm<sup>3</sup>, the repellency and the firmness-feeling of the resultant leather-like sheet are poor to damage hand touch like natural leather. On the other hand, if the apparent density of the fibrous substrate is more than 0.5 g/cm<sup>3</sup>, the firmness-feeling of the resultant leather-like sheet is lost or bad hand touch like rubber is exhibited.

[0022] Above all, a preferable fibrous substrate used in the present invention is a nonwoven fabric which has an apparent density of 0.25-0.50 g/cm<sup>3</sup> and is formed by using a shrinkable polyethylene terephthalate fiber as at least one part. If such a fibrous substrate is used, it is possible to obtain a leather-like sheet having very good softness and firmness-feeling. In this case, as the shrinkable polyethylene terephthalate fiber which makes the fibrous substrate, preferable is one having a shrinkage percentage of 10-60% in hot water of 70°C. The above-mentioned nonwoven fabric may be obtained by shrinking, in hot water, a nonwoven fabric disclosed in JP-A-37353/1981 and 53388/1978 resulting from use of an ordinary polyester fiber together with potentially spontaneously-extendable fiber at an appropriate ratio, and subsequently thermally-drying the resultant for the purpose of spontaneous extension.

[0023] It is preferable in the present invention that a fiber treating agent having a function for blocking the adhesion between the fiber and the composite resin is beforehand added to the above-mentioned fibrous substrate. By using the fibrous substrate to which the fiber treating agent has beforehand been added, impregnating this with the specific composite resin emulsion used in the present invention and solidifying the resin, the restraint of the fiber by the composite resin is weakened so as to make it easy to obtain a leather-like sheet that is highly soft and dense and is like natural leather.

[0024] The fiber treating agent for blocking the adhesion between the fiber and the composite resin may be preferably a silicone-based softening water-repellent. Specific examples of the silicone-based softening water-repellent include dimethylsilicone oil (oily dimethylpolysiloxane), methylphenylsilicone oil (oily methylphenylpolysiloxane), methylhydrogensilicone oil (oily methylhydrogenpolysiloxane, oily polysiloxane having a methylhydrogensiloxy unit and a dimethylsiloxy unit, or a mixture thereof), diorganopolysiloxane diol, fluorosilicone oil, silicone polyether copolymer, alkyl-modified silicone oil, higher fatty acid-modified silicone oil, amino-modified silicone oil and epoxy-modified silicone oil. One or more thereof may be used.

[0025] Among the above-mentioned silicone-based softening water-repellent, preferable are mixture of dimethylsilicone oil (oily dimethylpolysiloxane) and methylhydrogensilicone oil (oily methylhydrogenpolysiloxane, oily polysiloxane having a methylhydrogensiloxy unit and a dimethylsiloxy unit, or a mixture thereof) from the standpoint of good effect



of blocking the adhesion between the fiber and the composite resin, and easy availability. As the number of Si-H bonds is larger in the above-mentioned silicone oils, the water-repellency is higher and baking temperature can be made lower. Therefore, in the case that methylhydrogensilicone oil used together with dimethylsilicone oil is polysiloxane having a methylhydrogensiloxy unit and a dimethylsiloxy unit, it is preferable to use polysiloxane having 60 mole % or more of the methylhydrogensiloxy unit. The weight ratio of the dimethylsilicone oil to methylhydrogensilicone oil is preferably from 1/9 to 9/1. If the ratio of dimethylsilicone oil (dimethylpolysiloxane) is less than 10% by weight of the total, the hand touch of the resultant leather-like sheet tends to become hard. On the other hand, if the ratio of methylhydrogensilicone oil is less than 10% by weight of the total, the water-repellency of the resultant leather-like sheet tends to become insufficient.

[0026] The silicone-based softening water-repellent are e.g. an oil type, an emulsion type or a solution type. In the present invention, any one of them may be used. For industrial use, the emulsion type, wherein a silicone compound is emulsified or dispersed in water, is preferred. In order to give high water-repellency to the fibrous substrate at low temperatures, it is allowable to add into the silicon softening water-repellent a metal salt as a catalyst, such as a tin, titanium, zirconium or zinc salt of an organic acid.

[0027] The method for adding the above-mentioned fiber treating agent to the fibrous substrate may be any one of methods of adding the fiber treating agent homogeneously to the fibrous substrate. Above all, in the case that the fiber treating agent is, for example, the silicone-based softening water-repellent, it is preferable to adopt a method of diluting the softening water-repellent with water to prepare an aqueous liquid having a concentration of 0.5-5% by weight, optionally adding the catalyst to the liquid to prepare a treating liquid, immersing the fibrous substrate in the liquid, taking out the fibrous substrate from the liquid, squeezing the substrate to adjust the adhesion amount of the softening water-repellent, optionally pre-drying the substrate, and heating/drying it, or the like method. In order to cause the silicone-based softening water-repellent to adhere strongly on the fibrous substrate, the heating/drying temperature at that time is preferably from 50 to 150°C.

[0028] The adhesion amount (after heating/drying) of the fiber treating agent onto the fibrous substrate is preferably from 0.05 to 5% by weight and more preferably from 0.3 to 3% by weight. If the adhesion amount of the fiber treating agent is less than 0.05% by weight, the resultant leather-like sheet tends to have insufficient softness and water-repellency. On the other hand, if the adhesion amount is more than 5% by weight, the fiber treating agent is bled out onto the surface of the leather-like sheet so as to tend to cause deterioration in the feel of the surface, bad appearances and adhesion of the softening water-repellent onto others.

[0029] To improve washing-resistance of the leather-like sheet, the fibrous substrate may be optionally subjected to pre-treatment with e.g. an urethane resin, melamine resin, ethylene urea resin or glyoxal resin.

[0030] Besides the above-mentioned fibers, a more preferable fiber for the present invention is a microfibrillar fiber. In the case of the fibrous substrate comprising such a microfibrillar fiber-forming fiber, there is used a method of impregnating such a fibrous substrate with the composite resin emulsion, solidifying the resin, and converting the microfibrillar fiber-forming fiber into a microfibrillar fiber to prepare a leather-like sheet. This method makes the resultant sheet still better in softness, fulfillment feeling and hand touch like natural leather.

[0031] The microfibrillar fiber-forming fiber used in this method is preferably a microfibrillar fiber-forming composite spun fiber and/or blend spun fiber comprising two or more polymers. The fibrous substrate can be made to have a microfibrillar fiber structure in the leather-like sheet by dissolving and/or decomposing a part of the polymers which make the composite spun fiber and/or the blend spun fiber to remove the part and leave the remaining polymer as the microfibrillar fiber.

[0032] Typical examples of the microfibrillar fiber-forming composite spun fiber and/or blend spun fiber comprising two or more polymers are a sea-island type composite spun fiber and a sea-island blend spun fiber comprising two or more polymers. Its island component can be left in a microfibrillar form by dissolving and removing the polymer which makes the sea component from the above-mentioned fiber with an organic solvent, an alkali solution, or water, so that a microfibrillar fiber is prepared. The fibrous substrate used in the present invention may be made from one or both of the sea-island type composite spun fiber and the sea-island type blend spun fiber.

[0033] Examples of the polymer which makes the sea-island type composite spun fiber and the sea-island type blend spun fiber include polyesters such as polyethylene terephthalate, polybutylene terephthalate and modified polyester, polyamides such as 6-nylon, 6,12-nylon, 6,6-nylon and modified nylon; polyolefins such as polyethylene and polypropylene; polystyrene; polyvinylidene chloride; polyvinyl acetate; polymethacrylate; polyvinyl alcohol; and polyurethane elastomer. By selecting, from these polymers, two or more ones having different in solubility in an organic solvent, an alkali solution or water, it is possible to obtain a microfibrillar fiber-forming sea-island type composite spun fiber and sea-island blend type spun fiber wherein the island component can remain in a microfibrillar fiber form upon removal of the sea component by dissolution or decomposition. At that time, the island component may be made of only one polymer, or two or more polymers. In the case that the island component is made of two or more polymers, two or more microfibrillar fibers are present in the fibrous substrate after microfibrillar-fiber conversion.

[0034] The weight ratio of the island component to the sea component in the microfibrillar fiber-forming sea-island type composite spun fiber and sea-island type blend spun fiber is not especially limited. From the standpoint of easiness of



the production of the composite spun fiber or the blend spun fiber, easiness of microfibrillar conversion and physical properties of the resultant leather-like sheet, the weight ratio of the island component to the sea component is preferably from 15/85 to 85/15, and more preferably from 25/75 to 75/25.

[0035] In the microfibrillar fiber-forming sea-island type composite spun fiber or sea-island type blend spun fiber, the number of the island components, the fineness thereof and the dispersion state of the island component in the sea component are not especially limited. They may be any ones if the fibrous substrate comprising a microfibrillar fiber can be smoothly obtained.

[0036] The following leather-like sheet can be especially preferably used as raw material for artificial leather since it has excellent softness and fulfillment feeling and good hand touch like natural leather: the leather-like sheet obtained by impregnating the fibrous substrate made from a sea-island type composite spun fiber or sea-island type blend spun fiber whose sea component is polyethylene and/or polystyrene and whose island component is polyester and/or polyamide with a composite resin emulsion, solidifying the resin, dissolving/removing the polyethylene and/or the polystyrene as the sea component(s) with an organic solvent, for example, an aromatic hydrocarbon solvent such as benzene, toluene or xylene, or halogenated hydrocarbon such as carbon tetrachloride or perchloroethylene, in particular toluene to cause the polyester and/or the polyamide as the island(s) to remain in a microfibrillar fiber form.

[0037] The fibrous substrate comprising the microfibrillar fiber-forming fiber used in the present invention may be made, using the above-mentioned microfibrillar fiber-forming fiber together with optional other fiber materials unless the hand touch of the resultant leather-like sheet is damaged. Examples of the other fiber materials include ordinary fibers, shrinkable fibers, potentially spontaneously-extendable fibers, multilayer-laminating type potentially-separable fibers, and special porous fibers. One or more thereof may be used. The other fibers may be synthetic fibers such as polyester-based, polyamide-based, acryl-based, polyolefin-based, polyvinyl chloride-based, polyvinylidene chloride-based and polyvinyl alcohol-based fibers; semisynthetic fibers; and natural fibers such as cotton, wool and hemp.

[0038] The monofilament fineness of the microfibrillar fiber obtained from the microfibrillar fiber-forming fiber which makes the fibrous substrate is preferably 0.5 denier or less and more preferably from 0.001 to 0.4 denier since the fineness makes it possible to obtain a leather-like sheet excellent in softness, fulfillment feeling, and hand touch like natural leather.

[0039] In the same way as in the case of the above-mentioned ordinary fiber (that is, not any microfibrillar fiber-forming fiber), the thickness of the fibrous substrate comprising the microfibrillar fiber-forming fiber may be selected at will in accordance with uses of the resultant leather-like sheet. The thickness before the impregnation with the composite resin emulsion is preferably from 0.3 to 3.0 mm and more preferably from 0.6 to 2.5 mm since the thickness makes it possible to give appropriate hand touch like leather.

[0040] From the standpoint of softness of the resultant leather-like sheet, the apparent density of the fibrous substrate comprising the microfibrillar fiber-forming fiber is preferably from 0.1 to 0.5 g/cm<sup>3</sup> and more preferably from 0.15 to 0.45 g/cm<sup>3</sup> in the state that the fiber in the fibrous substrate is in a microfibrillar fiber form (in the state that the sea component has been removed to prepare a microfibrillar fiber in the case of using the above-mentioned sea-island type composite spun fiber and/or blend spun fiber). If the apparent density of the fibrous substrate is less than 0.1 g/cm<sup>3</sup>, the repellency and the firmness-feeling of the resultant leather-like sheet are poor to damage hand touch like natural leather. On the other hand, if the apparent density of the fibrous substrate is more than 0.5 g/cm<sup>3</sup>, the firmness-feeling of the resultant leather-like sheet is lost or bad hand touch like rubber tends to be exhibited.

[0041] In the present invention, in order to impregnate the fibrous substrate comprising the microfibrillar fiber-forming fiber homogeneously and promptly with the emulsion, it is also allowable to add an aqueous solution or aqueous emulsion of a surfactant exhibiting moist permeability to the fibrous substrate before the impregnation with the emulsion. In this case, it is necessary to perform the impregnation with the composite resin emulsion without drying/removing, from the fibrous substrate to which the aqueous solution or the dispersion solution of the surfactant is added, the solvent of the aqueous solution or the dispersant of the dispersion solution. When the drying is completely performed to remove the solvent of the aqueous solution or the dispersant of the dispersion solution, the above-mentioned effect cannot be expected. The amount of the surfactant added to the fibrous substrate is preferably from 0.01 to 20% by weight of the fibrous substrate. In the case that the fiber is the microfibrillar fiber-forming fiber, it is unnecessary to add any fiber treating agent having an action for blocking the adhesion between the fiber and the composite resin to the fibrous substrate comprising the microfibrillar fiber-forming fiber before the addition of the composite resin emulsion. This is because the sea component of the microfibrillar fiber-forming fiber is removed after the impregnation with the composite resin emulsion so as to produce spaces necessarily between the fiber and the composite resin.

[0042] Next, the fibrous substrate is impregnated with the composite resin emulsion having heat-sensible gelatinizing ability and then the resin is solidified. [the above-mentioned requirement (i)]

[0043] The heat-sensible gelatinizing ability referred to in the present invention is an emulsion whose fluidity is lost by heating to become a substance in a gel form. The heat-sensible gelatinizing temperature, at which the fluidity of the composite resin emulsion having the heat-sensible gelatinizing ability is lost by heating so that the emulsion turns into a gel form, is preferably from 30 to 70°C and more preferably from 40 to 70°C.



[0044] If the composite resin emulsion does not have the heat-sensible gelatinizing ability, phenomenon as follows are caused at the time of impregnating the fibrous substrate with the emulsion and drying the emulsion with hot air: movement of particles of the emulsion inside the fibrous substrate. Thus, the composite resin cannot be homogeneously dispersed or added into the fibrous substrate. Physical properties, such as stretch and softness, of the leather-like sheet drop. Moreover, its hand touch becomes bad. When the fibrous substrate is impregnated with the composite resin emulsion and then the emulsion is solidified in hot water, the emulsion is flown out in the hot water. In the same way as above, the composite resin cannot be homogeneously dispersed or added into the fibrous substrate to deteriorate physical properties, such as stretch and softness of the leather-like sheet, and the hand touch thereof.

[0045] The composite resin emulsion having the heat-sensible gelatinizing ability may be an emulsion comprising a composite resin having the heat-sensible gelatinizing ability by itself, or a composite resin emulsion wherein a heat-sensible gelatinizing agent is added to the emulsion so as to have the heat-sensible gelatinizing ability.

[0046] Examples of the heat-sensible gelatinizing agent for obtaining the composite resin emulsion having heat-sensible gelatinizing ability include inorganic salts, a polyethylene glycol type nonionic surfactant, polyvinylmethyl ether, polypropylene glycol, silicone polyether copolymer, and polysiloxane. One or more thereof may be used.

[0047] Above all, a combination of an inorganic salt and a polyethylene glycol type nonionic surfactant may be preferably used as the heat-sensible gelatinizing agent since it exhibits good heat-sensible gelatinizing ability. The inorganic salt in this case is preferably a monovalent or bivalent metal salt that makes it possible to lower the cloud point of the polyethylene glycol type nonionic surfactant. Specific examples thereof include sodium carbonate, sodium sulfate, calcium chloride, calcium sulfate, zinc oxide, zinc chloride, magnesium chloride, potassium chloride, potassium carbonate, sodium nitrate, and lead nitrate. One or more thereof may be used. Specific examples of the polyethylene glycol type nonionic surfactant include ethylene oxide adducts of higher alcohols, ethylene oxide adducts of alkylphenols, ethylene oxide adducts of fatty acids, ethylene oxide adducts of fatty acid esters of polyvalent alcohols, ethylene oxide adducts of higher alkylamines and ethylene oxide adducts of polypropylene glycol. One or more thereof may be used. In the case that an emulsion comprising a heat-sensible gelatinizing agent is used as the emulsion having heat-sensible gelatinizing ability, the amount of the heat-sensible gelatinizing agent is preferably from 0.2 to 20 parts by weight per 100 parts by weight of the resin in the emulsion.

[0048] The film of 100  $\mu\text{m}$  in thickness, obtained by drying the composite resin emulsion used in the present invention at 50°C, has an elastic modulus at 90°C of  $5.0 \times 10^8$  dyn/cm<sup>2</sup> or less [the above-mentioned requirement (ii)], preferably  $3.0 \times 10^8$  dyn/cm<sup>2</sup> or less and more preferably  $2.0 \times 10^8$  dyn/cm<sup>2</sup> or less, and in the case that the fiber which makes the fibrous substrate is not any microfibrillar fiber-forming fiber, the elastic modulus is  $1.0 \times 10^7$  dyn/cm<sup>2</sup> or more [the above-mentioned requirement (ii)], and preferably  $1.5 \times 10^7$  dyn/cm<sup>2</sup> or more. If there is used such a composite resin emulsion that supplies the dried film having an elastic modulus at 90°C of more than  $5.0 \times 10^8$  dyn/cm<sup>2</sup>, the resultant sheet has poor softness and hard hand touch. If there is used such a composite resin emulsion that supplies the dried film having an elastic modulus at 90°C of less than  $1.0 \times 10^7$  dyn/cm<sup>2</sup> in the case that the fiber which makes the fibrous substrate is not any microfibrillar fiber-forming fiber, the fiber is strongly restrained by the composite resin upon impregnation of the fibrous substrate with the emulsion and solidification of the resin therein. As a result, the resultant sheet has poor hand touch like fiber, which is neither dense nor like natural leather.

[0049] In the case that the fiber which makes the fibrous substrate is a microfibrillar fiber-forming fiber, it is preferred to use such a composite resin emulsion that supplies the dried film having an elastic modulus at 90°C of  $5.0 \times 10^6$  dyn/cm<sup>2</sup> or more.

[0050] In the case that the fiber which makes the fibrous substrate is a microfibrillar fiber-forming fiber, the film of 100  $\mu\text{m}$  in thickness, obtained by drying the composite resin emulsion at 50°C, has an elastic modulus at 160°C of  $5.0 \times 10^6$  dyn/cm<sup>2</sup> or more [the above-mentioned requirement (iii)], preferably  $8.0 \times 10^6$  dyn/cm<sup>2</sup> or more, and more preferably  $1.0 \times 10^7$  dyn/cm<sup>2</sup> or more. If there is used such a composite resin emulsion that supplies the dried film having an elastic modulus at 160°C of less than  $5.0 \times 10^6$  dyn/cm<sup>2</sup>, at the time of impregnating the fibrous substrate with the emulsion, solidifying the resin, extracting/removing the sea component of the sea-island type composite or blend spun fiber which makes the fibrous substrate with an organic solvent to prepare a microfibrillar fiber, the fibrous substrate becomes thin by pressure with e.g. a squeezing roller. That is, so-called "settling" is caused. Thus, the fibrous substrate has poor hand touch which causes loss of softness, fulfillment feeling and firmness-feeling. In the present invention, the method for measuring the elastic moduli at 90°C and 160°C of the above-mentioned dried film made from the composite resin emulsion is as described in Examples stated later.

[0051] The film of 100  $\mu\text{m}$  in thickness, obtained by drying the composite resin emulsion used in the present invention at 50°C, has  $\alpha$  dispersion temperature ( $T_\alpha$ ) of preferably -10°C or lower and more preferably -20°C or lower. Since the dried film obtained from the composite resin emulsion has the above-mentioned  $\alpha$  dispersion temperature ( $T_\alpha$ ), the resultant leather-like sheet is excellent in physical properties such as cold-resistance, and bending-resistance. The method for measuring the  $\alpha$  dispersion temperature ( $T_\alpha$ ) of the dried film in the present invention is as described in Examples stated later.

[0052] The composite resin emulsion used in the present invention is an emulsion that can be produced by emul-



sion-polymerizing an ethylenic unsaturated monomer (B) in the presence of a polyurethane-based emulsion (A) in the manner that a weight ratio of polyurethane in the component (A) to the (B) component is from 90/10 to 10/90 [the above-mentioned requirement (iv)].

[0053] The polyurethane contained in the polyurethane-based emulsion (A) can be generally obtained by reacting an appropriate composition of a macromolecular polyol, an organic diisocyanate compound, and a chain extender

[0054] Examples of the macromolecular polyol used in the production of the polyurethane include polyester polyol, polyether polyol, polycarbonate polyol, and polyester polycarbonate polyol. The polyurethane can be prepared by using one or more of these macromolecular polyols.

[0055] The polyester polyol that can be used in the production of the polyurethane can be produced, for example, by subjecting a polycarboxylic acid component, for example, an ester-forming derivative such as polycarboxylic acid, an ester thereof and an anhydride thereof to direct esterification or transesterification with a polyol component in a usual way. The polyester polyol may also be produced by subjecting a lactone to ring-opening polymerization.

[0056] The polycarboxylic acid component that is a raw material of the polyester polyol that can be used in the production of the polyurethane may be any one that is generally used in the production of polyester. Examples thereof include aliphatic dicarboxylic acids having 4-12 carbon atoms such as succinic acid, glutalic acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, dodecane diacid, methylsuccinic acid, 2-methylglutalic acid, 3-methylglutalic acid, trimethyladipic acid, 2-methyloctane diacid, 3,8-dimethyldodecane diacid, 3,7-dimethyldodecane diacid; alicyclic dicarboxylic acids such as cyclohexane dicarboxylic acid; aromatic dicarboxylic acids such as terephthalic acid, isophthalic acid, orthophthalic acid, naphthalene dicarboxylic acid; tricarboxylic acids such as trimellitic acid and trimesic acid; and ester-forming derivatives thereof. The polyester polyol can be prepared by using one or more of the above-mentioned polycarboxylic acid components. Above all, the polyester polyol is preferably a polyester polyol prepared by using an aliphatic dicarboxylic acid or an ester-forming derivative thereof as the polycarboxylic acid component.

[0057] Examples of the polyol component that is a raw material of the polyester polyol that can be used in the production of the polyurethane include aliphatic diols having 2-15 carbon atoms such as ethylene glycol, diethylene glycol, triethylene glycol, propylene glycol, 1,3-propanediol, 2-methyl-1,3-propanediol, 2,2-diethyl-1,3-propanediol, 1,3-butylene glycol, 1,4-butanediol, 3-methyl-1,5-pentanediol, 1,6-hexanediol, 1,8-octanediol, 2-methyl-1,8-octanediol, 2,7-dimethyl-1,8-octanediol, 1,9-nonanediol, 2,8-dimethyl-1,9-nonanediol, 1,10-decanediol; alicyclic diols such as 1,4-cyclohexanediol, cyclohexanedimethanol and dimethylcyclooctane dimethanol; aromatic diols such as 1,4-bis( $\beta$ -hydroxyethoxy) benzene; polyalkylene glycols; polyols such as glycerin, trimethylolpropane, butanetriol and pentaerythritol. One or more thereof can be used. Above all, the polyester polyol is preferably any polyester polyol prepared using aliphatic polyol.

[0058] The lactone that is a raw material of the polyester polyol that can be used in the production of the polyurethane is, for example,  $\epsilon$ -caprolactone, or  $\beta$ -methyl- $\delta$ -valerolactone.

[0059] Examples of the polyether polyol that can be used in the production of the polyurethane include polyethylene glycol, polypropylene glycol, polytetramethylene glycol, and poly(methyltetramethyleneglycol). One or more thereof may be used.

[0060] The polycarbonate polyol that can be used in the production of the polyurethane may be, for example, any polycarbonate polyol obtained by reacting a polyol with a carbonate compound such as dialkyl carbonate, diaryl carbonate or alkylene carbonate. The polyol that is a raw material of the polycarbonate polyol may be any polyol listed up as the polyol that is a raw material of the polyester polyol. The dialkyl carbonate may be e.g. dimethyl carbonate or diethyl carbonate.

[0061] The diaryl carbonate may be e.g. diphenyl carbonate. The alkylene carbonate may be e.g. ethylene carbonate.

[0062] The polyester polycarbonate polyol that can be obtained in the production of the polyurethane may be, for example, one obtained by reacting polyol, polycarboxylic acid and a carbonate compound simultaneously, one obtained by reacting polyester polyol that has been beforehand prepared with a carbonate compound, one obtained by reacting polycarbonate polyol that has been beforehand prepared with polyol and polycarboxylic acid, or one obtained by reacting polyester polyol and polycarbonate polyol that have been beforehand prepared.

[0063] The number-average molecular weight of the macromolecular polyol used in the production in the polyurethane is preferably from 500 to 10000, more preferably from 700 to 5000, and still more preferably from 750 to 4000. The number-average molecular weight of the macromolecular polyol referred to in the present invention is a number-average molecular weight calculated on the basis of the hydroxyl value measured according to JIS K 1577.

[0064] In the macromolecular polyol used in the production of the polyurethane, the number of hydroxyl groups per molecule thereof may be more than 2 unless the production of the polyurethane-based emulsion (A) is hindered. The macromolecular polyol having more than 2 hydroxyl groups per molecule thereof, for example, polyester polyol can be produced by using, as a part of polyol components, polyol such as glycerin, trimethylolpropane, butanetriol, hexanetriol, trimethylolbutane or pentaerythritol.

[0065] The sort of the organic diisocyanate compound used in the production of the polyurethane is not especially



limited, and may be any one of known aliphatic diisocyanates, alicyclic diisocyanates and aromatic diisocyanates that have in their molecule isocyanate groups and have been hitherto used in the production of polyurethane-based emulsion. Specific examples of the organic diisocyanate compounds that can be used in the production of the polyurethane include isophorone diisocyanate, tolylene diisocyanate, 4,4'-diphenylmethane diisocyanate, p-phenylene diisocyanate, 1,5-naphthylene diisocyanate, xylylene diisocyanate, hexamethylene diisocyanate, 4,4'-dicyclohexylmethane diisocyanate, 3,3'-dichloro-4,4'-diphenylmethane diisocyanate, and hydrogenated xylylene diisocyanate. One or more of these organic diisocyanates may be used.

[0066] In the case that the fibrous substrate is made of a microfine fiber-forming fiber, it is preferred to use an aromatic diisocyanate, such as tolylene diisocyanate or 4,4'-diphenylmethane diisocyanate, selected from the above-mentioned organic diisocyanates since the polyurethane obtained from it is excellent in solvent-resistance. In the case of using the composite resin emulsion comprising the polyurethane obtained using such an aromatic diisocyanate, at the time of impregnating the fibrous substrate comprising the sea-island type composite and/or blend spun fiber with the composite resin emulsion, solidifying the emulsion and extracting/removing the sea component in the fiber with a solvent to prepare a microfine fiber, the drop in physical properties of the composite resin with the organic solvent is suppressed because of excellent solvent-resistance of the composite resin. Thus, it is possible to obtain a leather-like sheet excellent in hand touch and mechanical properties.

[0067] In the case that the fiber which makes the fibrous substrate is not any microfine fiber-forming fiber, it is especially preferred to use isophorone diisocyanate, tolylene diisocyanate, 4,4'-diphenylmethane diisocyanate or 4,4'-dicyclohexylmethane diisocyanate among the above-mentioned diisocyanates.

[0068] The chain extender used in the production of the polyurethane may be any one of chain extenders that have been hitherto used in the production of polyurethane-based emulsion. It is especially preferred to use a low-molecule compound which has in the molecule thereof 2 or more active hydrogen atoms that can be reacted with isocyanate groups and which has a molecular weight of 400 or less. Examples of such a chain extender include diamines such as hydrazine, ethylenediamine, propylenediamine, isophoronediamine, piperazine and derivatives thereof, phenylenediamine, tolylenediamine, xylylenediamine, adipic dihydrazide, isophthalic dihydrazide, hexamethylenediamine, 4,4'-diaminodiphenylmethane, 4,4'-dicyclohexylmethanediamine; triamines such as diethylenetriamine; diols such as ethylene glycol, propylene glycol, 1,4-butanediol, 1,6-hexanediol, 3-methyl-1,5-pentanediol, neopentylglycol, 1,4-cyclohexanediol, bis-( $\beta$ -hydroxyethyl)terephthalate, xylylene glycol, 1,4-bis( $\beta$ -hydroxyethoxy)benzene; and aminoalcohols such as aminoethyl alcohol and aminopropyl alcohol. One or more thereof may be used. Above all, it is preferred to use ethylene glycol, isophoronediamine, ethylenediamine or diethylenetriamine.

[0069] The polyurethane-based emulsion (A) preferably has, in its polyurethane skeleton, from 5 to 25 mmol of neutralized carboxylic groups or sulfonic groups per 100 g of the polyurethane from the standpoint of polymerization stability upon emulsion-polymerization of the ethylenic unsaturated monomer (B) and easy supply of heat-sensible gelatinizing ability. The neutralized carboxylic groups or sulfonic groups can be introduced into the polyurethane skeleton by using a compound having carbonic groups or sulfonic groups or salts of these groups and having one or more active hydrogen atoms of a hydroxyl group, an amino group or the like as one of raw materials for the production of the polyurethane, optionally using a base compound such as a tertiary amine or an alkali metal, and neutralizing the carboxylic groups or sulfonic groups. Examples of such a compound include carboxylic group-containing compounds such as 2,2-bis(hydroxymethyl)propionic acid, 2,2-bis(hydroxymethyl)butyric acid and 2,2-bis(hydroxymethyl)valeric acid, and derivatives thereof; sulfonic group-containing compounds such as 1,3-phenylenediamine-4,6-disulfonic acid and 2,4-diaminotoluene-5-sulfonic acid, and derivatives thereof. There may be used polyester polyol or polyester polycarbonate obtained by copolymerizing the above-mentioned compounds. Especially preferred is a method of using 2,2-bis(hydroxymethyl)propionic acid or 2,2-bis(hydroxymethyl)butyric acid to produce a polyurethane prepolymer and adding a base compound such as triethyl amine, trimethylamine, sodium hydroxide or potassium hydroxide thereto after the end of the reaction of the prepolymer to perform neutralization.

[0070] Upon the production of the polyurethane, in order to improve solvent-resistance, heat-resistance, resistance against hot water and the like, the polyurethane may be optionally reacted with a polyol having tri- or more-functionality, such as trimethylolpropane, or an amine having tri- or more-functionality to cause the polyurethane to have therein a crosslink structure.

[0071] The polyurethane-based emulsion (A) used in the present invention can be produced in the same manner as has been hitherto used for the production of any polyurethane-based emulsion. Examples thereof include the method (1) of producing an urethane prepolymer having an isocyanate group at its terminal, and forcibly emulsifying the prepolymer into water in the presence of an emulsifier by highly mechanical shearing force and simultaneously or subsequently completing chain-extending reaction with an appropriate chain extender to prepare a polyurethane emulsion having a high molecular weight; and the method (2) of using a hydrophilic macromolecular polyol to produce a self-emulsifying polyurethane, and emulsifying the polyurethane into water without use of any emulsifier to produce a polyurethane-based emulsion. For the emulsification, there can be used an emulsifying/dispersing machine such as a homomixer or a homogenizer. At that time, in order to suppress reaction of the isocyanate group with water, it is preferred



to set emulsifying temperature to 40°C or lower.

[0072] The emulsifier in the method (1) preferably comprises 0.5 to 6g of a surfactant per 100 g of polyurethane because of easy supply of heat-sensible gelatinizing ability and polymerization stability upon emulsion-polymerization of the ethylenic unsaturated monomer (B) in the presence of the polyurethane-based emulsion (A). Examples of such a surfactant include anionic surfactants such as sodium lauryl sulfate, ammonium lauryl sulfate, sodium polyoxyethylene-  
 5 a surfactant include anionic surfactants such as sodium lauryl sulfate, ammonium lauryl sulfate, sodium polyoxyethylene-  
 enetri-decylether acetate, sodium dodecylbenzenesulfonate, sodium alkyl-diphenylether disulfonate and sodium di(2-ethylhexyl) sulfosuccinate; and nonionic surfactants such as polyoxyethylene nonylphenyl ether, polyoxyethylene octylphenyl ether, polyoxyethylene lauryl ether, polyoxyethylene stearyl ether, and polyoxyethylene-polyoxypropylene block copolymer. Above all, preferable are the anionic surfactants such as sodium lauryl sulfate, sodium polyoxyethylenetri-  
 10 decylether acetate and ammonium lauryl sulfate.

[0073] The composite resin emulsion used in the present invention is produced by emulsion-polymerizing the ethylenically unsaturated monomer (B) in the presence of the polyurethane-based emulsion (A). The weight ratio of the polyurethane in the polyurethane-based emulsion (A) to the ethylenically unsaturated monomer (B) is from 90/10 to 10/90, preferably from 85/15 to 15/85 and still more preferably 80/20-20/80. If the proportion of the polyurethane is less  
 15 than 10% by weight, the elastic modulus of the composite resin becomes high to deteriorate the hand touch of the resultant leather-like sheet. If the proportion of the polyurethane is more than 90% by weight, the weather-resistance and hydrolysis-resistance of the composite resin deteriorate and further costs rise.

[0074] In the case that the fibrous substrate is a microfine fiber-forming fiber, the ethylenically unsaturated monomer (B) preferably comprises 90 to 99.9% by weight of a monofunctional ethylenically unsaturated monomer (B1) made  
 20 mainly of a derivative of (meth)acrylic acid and 10 to 0.1% by weight of a polyfunctional (not less than bifunctional) ethylenically unsaturated monomer (B2) because of more satisfactory hand touch and weather-resistance of the resultant leather-like sheet. The ethylenically unsaturated monomer (B) more preferably comprises 92 to 99.8% by weight of the monofunctional ethylenic unsaturated monomer (B1) and 8 to 0.2% by weight of the polyfunctional ethylenically unsaturated monomer (B2). Even when the fibrous substrate is other than any microfine fiber-forming fiber, the monofunctional  
 25 ethylenic unsaturated monomer (B1) and the polyfunctional ethylenically unsaturated monomer (B2) are preferably used together as the above-mentioned ethylenic unsaturated monomer (B) at the above-mentioned ratio to improve endurance of the resultant composite resin.

[0075] Examples of the monofunctional ethylenically unsaturated monomer (B1) used in the production of the composite resin emulsion include derivatives of (meth)acrylic acid such as methyl (meth)acrylate, ethyl (meth)acrylate, butyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, lauryl (meth)acrylate, stearyl (meth)acrylate, cyclohexyl (meth)acrylate, isobornyl (meth)acrylate, benzyl (meth)acrylate, (meth)acrylic acid, glycidyl (meth)acrylate, dimethylaminoethyl (meth)acrylate, diethylaminoethyl (meth)acrylate, 2-hydroxyethyl (meth)acrylate and 2-hydroxypropyl (meth)acrylate; aromatic vinyl compounds such as styrene,  $\alpha$ -methylstyrene and p-methylstyrene; acrylamides such as acrylamide, diacetone acrylamide, methacrylamide and maleic amide; maleic acid, fumaric acid, itaconic acid and derivatives thereof; heterocyclic vinyl compounds such as vinylpyrrolidone; vinyl compounds such as vinyl chloride, acrylonitrile, vinyl ether, vinyl ketone and vinyl amide;  $\alpha$ -olefins such as ethylene and propylene. One or more thereof may be used. About the monofunctional ethylenically unsaturated monomer (B1), the proportion of the derivative of (meth)acrylic acid is preferably 60% or more, more preferably 70% or more and still more preferably 80% or more by weight.

[0076] Examples of the polyfunctional (not less than bifunctional) ethylenically unsaturated monomer used in the production of the composite resin emulsion include diacrylates such as ethylene glycol di(meth)acrylate, diethylene glycol di(meth)acrylate, triethylene glycol di(meth)acrylate, polyethylene glycol di(meth)acrylate, 1,4-butanediol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, 1,9-nonanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate, dimethyloctadecane di(meth)acrylate and glycerin di(meth)acrylate; tri(meth)acrylates such as trimethylolpropane tri(meth)acrylate and pentaerythritol tri(meth)acrylate; tetra(meth)acrylates such as pentaerythritol tetra(meth)acrylate; polyfunctional aromatic vinyl compounds such as divinylbenzene and trivinylbenzene; compounds containing two or more ethylenic unsaturated bonds which are different from each other, such as allyl (meth)acrylate and vinyl (meth)acrylate; urethane acrylates having a molecular weight of 1500 or less, such as a 2:1 addition reaction product of 2-hydroxy-3-phenoxypropyl acrylate and hexamethylenediisocyanate, a 2:1 addition reaction product of pentaerythritol triacrylate and hexamethylenediisocyanate and a 2:1 addition reaction product of glycerin dimethacrylate and tolylene-  
 45 diisocyanate. One or more thereof may be used.

[0077] The ethylenically unsaturated monomer (B) may be added to the polyurethane-based emulsion (A) collectively, separately or continuously. It is allowable to perform multi-step polymerization, wherein the composition of monomers is changed in the respective steps of polymerization, or a power feed method, wherein the composition of monomers is continuously changed. In the multi-step polymerization or the polymerization by the power feed method, the total amount of the polyfunctional (not less than bifunctional) ethylenically unsaturated monomer (B2) is preferably  
 55 from 0.1 to 10% by weight of the whole of the ethylenically unsaturated monomer (B) used in the polymerization. An emulsifier such as a surfactant may be appropriately added upon the polymerization of the ethylenically unsaturated monomer (B).



[0078] Especially preferable is a method of emulsion-polymerizing an acrylic acid derivative-based monomer firstly and then emulsion-polymerizing a methacrylic acid derivative-based monomer or an aromatic vinyl monomer because products obtained from the resultant composite resin emulsion have highly elastic performance of polyurethane. The acrylic acid derivative-based monomer, the methacrylic acid derivative monomer, and the aromatic vinyl monomer used at this time may be the above-mentioned acrylic acid derivative-based monomer, methacrylic acid derivative-based monomer and aromatic vinyl monomer. At this time, the weight ratio of the acrylic acid derivative-based monomer to the methacrylic acid derivative-based monomer or the aromatic vinyl monomer (in the case that the methacrylic acid derivative-based monomer and the aromatic vinyl monomer are used together, the total amount thereof) is from 50/50 to 99/1.

[0079] Examples of a polymerization initiator used in the polymerization of the ethylenically unsaturated monomer (B) include oil-soluble peroxides such as benzoylperoxide, lauroylperoxide, dicumylperoxide, di t-butylperoxide, cumenehydroperoxide, t-butylhydroperoxide, diisopropylbenzenehydroperoxide; oil-soluble azo compounds such as 2,2'-azobisisobutyronitrile and 2,2'-azobis-(2,4-dimethylvaleronitrile; water-soluble peroxides such as hydrogen peroxide, potassium persulfate, sodium persulfate and ammonium persulfate; water-soluble azo compounds such as azobiscyanovaleric acid, 2,2'-azobis-(2-amidinopropane)bishydrochloride. One or more thereof may be used. Above all, the oil-soluble initiators such as the oil-soluble peroxide and the oil-soluble azo compounds are preferable. It is allowable to use a redox initiator using a reducing agent and optional chelating agent, together with the above-mentioned polymerization initiator. Examples of the reducing agent include formaldehyde alkali metal sulfoxylate such as Rongalite (sodium formaldehyde sulfoxylate); sulfites such as sodium sulfite and sodium hydrogensulfite; pyrosulfites such as sodium pyrosulfite; thiosulfates such as sodium thiosulfate; phosphites such as phosphorous acid and sodium phosphite; pyrophosphites such as sodium pyrophosphite; mercaptans; ascorbates such as ascorbic acid and sodium ascorbate; erythorbates such as erythorbic acid and sodium erythorbate; sugars such as glucose and dextrose; and metal salts such as ferrous sulfate and copper sulfate. Examples of the chelating agent include sodium pyrophosphate and ethylenediaminetetraacetate. The use amount of each of these initiator, reducing agent and chelating agent is decided by combination thereof in each initiator system.

[0080] The composite resin emulsion used in the present invention may comprise another polymer unless the property of the resultant leather-like sheet is damaged. Examples thereof include synthetic rubbers such as an acrylonitrile-butadiene copolymer, polybutadiene, and polyisoprene; and synthetic polymers having elasticity such as an ethylene-propylene copolymer, polyacrylate, an acrylic copolymer, silicone, other polyurethanes, polyvinyl acetate, polyvinyl chloride, a polyester-polyether block copolymer and an ethylene-vinyl acetate. The composite resin emulsion may comprise one or more of these polymers.

[0081] If necessary, the composite resin emulsion may comprise one or more of known additives such as an anti-oxidant, an ultraviolet ray absorber, a surfactant such as a penetrant; a thickener, a mildew resistant agent, a water-soluble macromolecular compound such as polyvinyl alcohol or carboxymethylcellulose, a dye, a pigment, a filler, and a solidification adjuster. The thus obtained composite resin emulsion may be used as not only a leather-like sheet but also e.g. as a film-forming material, a paint, a coating agent, a fiber treating agent, an adhesive or a glass fiber converging agent.

[0082] The method for impregnating the fibrous substrate comprising the fiber with the composite resin emulsion may be any method if the method makes it possible to impregnate the fibrous substrate homogeneously with the emulsion. In general, it is preferred to adopt a method of immersing the fibrous substrate into the composite resin emulsion. The fibrous substrate is impregnated with the emulsion and subsequently a press roll or a doctor blade is used to adjust the amount of the impregnation with the emulsion to an appropriate amount.

[0083] Next, the composite resin emulsion with which the fibrous substrate is impregnated is heated to be solidified. Examples of the method for heating and solidifying the composite resin emulsion include the method (1) of immersing the fibrous substrate impregnated with the emulsion into a hot water bath of 70 to 100°C to solidify the emulsion, the method (2) of spraying heated water vapor of 100 to 200°C on the substrate impregnated with the emulsion to solidify the emulsion, and the method (3) of introducing the substrate impregnated with the emulsion, as it is, into a drying machine of 50 to 150°C and drying it by heating to solidify the emulsion.

[0084] Above all, it is preferred to adopt the solidifying method (1) in the hot water bath or the solidifying method (2) using the heated water vapor because the method makes it possible to obtain a leather-like sheet having softer hand touch. The temperature for solidifying the composite resin emulsion in the methods (1)-(3) is preferably a temperature at least 10°C higher than the heat-sensible gelatinizing temperature of this emulsion to prevent uneven distribution of the composite resin in the fibrous substrate by prompt completion of the solidification of the emulsion. In the case of using the solidifying method (1) or (2), the solidified leather-like sheet is dried by heating or air, to remove water contained in the leather-like sheet.

[0085] In the leather-like sheet which is finally obtained by impregnating the fibrous substrate with the composite resin emulsion, solidifying the emulsion and drying the solidified sheet, the adhesion amount of the polymer in the leather-like sheet (in the case that the composite resin emulsion comprises a different polymer, the adhesion amount



of all the polymers including the different polymer) is preferably from 5 to 150%, more preferably from 10 to 100%, and still more preferably from 20 to 80% by weight of the fibrous substrate (in the case that the fibrous substrate comprises a microfibrillar fiber-forming fiber, the weight of the fibrous substrate after being converted into a microfibrillar fiber). If the adhesion amount of the polymer is less than 5% by weight, the fulfillment feeling of the resultant leather-like sheet is insufficient so that hand touch like natural leather may not be obtained. On the other hand, if the adhesion amount is more than 150% by weight, the resultant sheet becomes hard so that hand touch like natural leather may not be obtained.

[0086] In the case that the fibrous substrate is composed of a microfibrillar fiber-forming fiber in the present invention, a leather-like sheet is produced by impregnating the fibrous substrate with the composite resin emulsion, solidifying the emulsion, and subsequently converting the microfibrillar fiber-forming fiber into a microfibrillar fiber bundle [the above-mentioned requirement (v)]. In the case that at that time the fibrous substrate is made from the above-mentioned sea-island type composite and/or blend spun fiber, after the impregnation with the composite resin emulsion and the solidification thereof, the sea component in the fiber is dissolved/removed with e.g. an organic solvent to cause the island component to remain in a microfibrillar fiber form. Thus, a leather-like sheet is produced. The removing treatment of the sea component with the organic solvent in this case can be conducted in accordance with the method or conditions that have been hitherto adopted in the production of artificial leather. The step of converting the microfibrillar fiber-forming fiber into a microfibrillar fiber bundle after the solidification of the composite resin emulsion has an effect of removing the sea component of the sea-island type fiber restrained by the composite resin and causing the microfibrillar fiber that is the island component which does not contact the composite resin to remain so as to weaken restraint of the composite resin into the fibrous substrate comprising the microfibrillar fiber throughout the resultant leather-like sheet.

[0087] The leather-like sheet of the present invention, obtained by the above-mentioned process, has high softness, fulfillment feeling, and good hand touch like natural leather. This sheet is never inferior to artificial leather obtained by the conventional wet solidifying method. According to results from observation with an electron microscope by the inventors, in the leather-like sheet of the present invention, the fiber in the fibrous substrate is not strongly restrained by the composite resin. It is also observed that, in the case of converting the fiber into a microfibrillar fiber bundle, the composite resin is solidified to be filled into gaps between the bundle of the microfibrillar fibers in the state of causing appropriate spaces to remain in the bundles of the microfibrillar fiber. Therefore, according to the leather-like sheet of the present invention, it is possible to prevent a drop in softness caused by the restraint of the fiber and settling of the sheet. Moreover, it is possible to obtain a leather-like sheet having better softness and fulfillment feeling than conventional leather-like sheets in the form of impregnation with emulsion, and having excellent hand touch that is very similar to natural leather by an increase in the apparent filling amount of resin parts by filling spaces between the fibers (in the case that the fiber is made into a microfibrillar form, spaces between the bundle of the microfibrillar fibers) with composite resin particles.

[0088] The above-mentioned excellent properties of the leather-like sheet of the present invention is used to apply the present invention to wide products such as a mattress, a liner material of a bag, a core material for clothing, a core material for shoes, a cushion material, interior furnishings of a car, a train or an airplane, a wall material and a carpet. In the case that the fiber is made into a microfibrillar fiber form, the microfibrillar fiber may be subjected to buffing to obtain an artificial leather sheet like suede. It can be suitably used as clothing, a cover material for furniture such as a chair or a sofa, a cover for a sheet of a train or a car, wallpaper or gloves. If a polyurethane layer is disposed onto a single side of the leather-like sheet of the present invention, the resultant can be suitably used as an artificial leather with a grain-like surface, which is used for sports shoes, shoes for gentlemen, a bag, a handbag or a satchel.

[0089] The following will specifically describe the present invention by way of Examples, but the present invention is not limited thereto. In the following Examples and Comparative Examples, the heat-sensible gelatinizing temperature, the elastic modulus of films at 90°C and 160 °C,  $\alpha$  dispersion, and softness and hand touch of sheets are measured or estimated by the following methods.

[Heat-sensible gelatinizing temperature]

[0090] Ten grams of an emulsion were weighted out and put into a test tube. The test tube was shaken in a hot water bath whose temperature was constantly kept at 90°C to raise the temperature of the test tube. The temperature of the emulsion when its fluidity was lost so that the emulsion turned into a gel was defined as heat-sensible gelatinizing temperature.

[Elastic moduli at 90°C and 160 °C and  $\alpha$  dispersion]

[0091] A film of 100  $\mu$ m in thickness which was obtained by drying an emulsion at 50°C was heated at 130°C for 10 minutes. Thereafter, a viscoelasticity measuring device (FT Rheospectoler "DVE-V4", made by Rheology Company) was used to measure, at a frequency of 11 HZ, the elastic moduli (E) at 90°C and 160 °C, and the  $\alpha$  dispersion tem-



perature ( $T_a$ ) of the film.

[Softness]

- 5 [0092] A leather-like sheet was cut into a piece 10 cm square. At room temperature of 20°C, a pure bending test machine ("KES-FB2-L" made by KATO TEKKO) was used to measure the flexural rigidity ratio ( $\text{gfcm}^2/\text{cm}$ ) of the piece along the direction perpendicular to the direction along which the nonwoven fabric used in the production of the leather-like sheet was wound. The flexural rigidity ratio was used as the index of softness.

10 [Bending fatigue resistance]

- [0093] A leather-like sheet was cut into a piece of 7 cm x 4.5 cm. According to JIS-K 6545, a flexibility test device ("Flexometer" made by Bally Company) was used to perform a bending test at 20°C. Every time when the sheet piece was bent 100,000 times, the surface state of the sheet piece was observed to measure the number of the bending operations until a crack or a slit was generated. In the case that any crack or slit was not generated even when the sheet piece was bent 500,000 times, its bending fatigue resistance and its endurance were sufficiently good. This case was evaluated as "good".

[Hand touch]

- 20 [0094] A leather-like sheet was touched with hands. The case wherein the sheet had hand touch like natural leather was evaluated as "good". The case wherein the sheet was harder than natural leather to have insufficient softness, and/or the case wherein the sheet was insufficient fulfillment feeling not to have hand touch like natural leather were evaluated as "bad".

- 25 [0095] Abbreviated symbols used in Examples and Comparative Examples are shown in Tables 1 and 2.

Table 1

Abbreviated symbols	Names of compounds
PMPA2000	Polyester diol having a number-average molecular weight of 2000 (produced by reacting 3-methyl-1,5-pentanediol with adipic acid)
PTMG1000	Polytetramethylene glycol having a number-average molecular weight of 1000
PHC2000	Polyhexamethylene carbonate glycol having a number-average molecular weight of 2000
PCL2000	Polycaprolactone glycol having a number-average molecular weight of 2000
TDI	2,4-Tolylene diisocyanate
MDI	4,4'-Diphenylmethane diisocyanate
DMPA	2,2-Bis(hydroxymethyl)propionic acid
MEK	2-Butanone
TEA	Triethylamine
DETA	Diethylenetriamine
IPDA	Isophoronediamine
EDA	Ethylenediamine

Table 2

Abbreviated symbols	Names of compounds
BA	Butyl acrylate
EHA	2-Ethylhexyl acrylate



Table 2 (continued)

Abbreviated symbols	Names of compounds
MMA	Methyl methacrylate
St	Styrene
HDDA	1,6-Hexanediol diacrylate
ALMA	Allyl methacrylate
CHP	Cumenehydroperoxide

[Reference Example 1] (Production of a fibrous substrate)

[0096] 60 parts by weight of 6-nylon and 40 parts by weight of high-fluidity polyethylene were blend-spun, stretched, and cut to obtain a sea-island type blend spun fiber (monofilament fineness: 4 deniers, fiber length: 51 mm, and island component: 6-nylon). This fiber was subjected to steps using a card, a cross lapper, and a needle punch, to obtain a fiber-entangled nonwoven fabric having an apparent density of  $0.160 \text{ g/cm}^3$ . This nonwoven fabric was heated to melt the polyethylene as the sea component and fix elements which made the fiber thermally to each other, thereby giving a fiber-entangled nonwoven fabric of  $0.285 \text{ g/cm}^3$  in apparent density, both surface of which were made smooth. (This fabric is referred to as the nonwoven fabric ① hereinafter.)

[Reference Example 2] (Production of a fibrous substrate)

[0097] 70 parts by weight of polyethylene terephthalate and 30 parts by weight of low-density polyethylene were used to produce a sea-island type composite spun fiber (monofilament fineness: 4 deniers, fiber length: 51 mm, island component: polyethylene terephthalate, and the number of the islands in a cross section of the fiber: 15). This fiber was subjected to steps using a card, a cross lapper, and a needle punch, to obtain a fiber-entangled nonwoven fabric. Next, the fabric was immersed into hot water of  $70^\circ\text{C}$  to shrink the fabric in the manner that its shrinkage percentage in area would be 30%. Thereafter, the polyethylene as the sea component was melted to fix elements which made the fiber thermally to each other, thereby giving a fiber-entangled nonwoven fabric of  $0.35 \text{ g/cm}^3$  in apparent density, both surface of which were made smooth. (This fabric is referred to as the nonwoven fabric ② hereinafter.)

[Reference Example 3] (Production of a fibrous substrate)

[0098] 70 parts by weight of polyethylene terephthalate and 30 parts by weight of polystyrene were used to produce a sea-island type composite spun fiber (monofilament fineness: 4 deniers, fiber length: 51 mm, island component: polyethylene terephthalate, and the number of the islands in a cross section of the fiber: 15). The same way as in Reference Example 2 was performed to give a fiber-entangled nonwoven fabric of  $0.32 \text{ g/cm}^3$  in apparent density, both surface of which were made smooth. Elements which made the fiber were thermally fixed to each other. (This fabric is referred to the nonwoven fabric ③ hereinafter.)

[Reference Example 4] (Production of a fibrous substrate)

[0099] A polyethylene terephthalate fiber (monofilament fineness: 2 deniers, fiber length: 51 mm, and shrinkage percentage in hot water of  $70^\circ\text{C}$ : 25%) was used to produce a web having a weight of  $240 \text{ g/m}^2$  through a card and a cross lapper. This web was passed through a needle locker room so as to be subjected to a needle punch treatment at 700 needles/ $\text{cm}^2$ . Thereafter, the web was immersed in hot water of  $70^\circ\text{C}$  for 2 minutes to shrink the web into 56% of the original area. This was pressed at  $155^\circ\text{C}$  with a cylinder belt press machine to produce a nonwoven fabric having a thickness of 1.2 mm, a weight of  $360 \text{ g/cm}^2$  and an apparent density of  $0.30 \text{ g/cm}^3$ . This nonwoven fabric was impregnated with an emulsion (solid concentration: 5% by weight) of a silicone-based softening water-repellent comprising dimethylpolysiloxane (KF96L" made by Shin-Etsu Chemical Co., Ltd.) and methylhydrogenpolysiloxane (KF99" made by Shin-Etsu Chemical Co., Ltd.), the weight ratio of which was 1/1. The nonwoven fabric was squeezed with a roll, and then dried at  $130^\circ\text{C}$  for 30 minutes to give a nonwoven fabric to which the silicone-based softening water-repellent adhered in an amount of 1.2% by weight of the nonwoven fabric. (This fabric is referred to as the nonwoven fabric ④ hereinafter.)



[Reference Example 5] (Production of a fibrous substrate)

[0100] A common polyethylene terephthalate fiber (monofilament fineness: 2.5 deniers) and a nylon fiber (monofilament fineness: 1.5 deniers) were used at a weight ratio of 35/65 to produce a fiber-entangled nonwoven fabric (thickness: 1.4 mm, and apparent density: 0.25 g/cm<sup>3</sup>). This fabric was impregnated with a 5 weight % aqueous solution of a silicone-based softening water-repellent ("Gelalex SH" made by Matsumoto Yushi-Seiyaku Co., Ltd.). The nonwoven fabric was squeezed with a roll, and then dried at 130°C for 30 minutes to give a nonwoven fabric to which the silicone-based softening water-repellent adhered in an amount of 1.0% by weight of the nonwoven fabric. (This fabric is referred to as the nonwoven fabric ⑤ hereinafter.)

[Reference Example 6] (Production of a polyurethane-based emulsion)

[0101] Into a three-neck flask were weight out 300.0 g of PMPA2000, 60.87 g of TDI, and 7.85 g of DMPA, and the mixture was stirred in the atmosphere of dry nitrogen at 90°C for 2 hours to react hydroxyl groups in the present system quantitatively. Thus, a prepolymer having an isocyanate terminal was obtained. To this prepolymer were added 195.4 g of MEK, and the mixture was homogeneously mixed. Thereafter, the temperature inside the flask was lowered to 40°C, and then 5.92 g of TEA were added thereto followed by stirring for 10 minutes. Next, an aqueous solution wherein 7.83 g of sodium lauryl sulfate were dissolved in 285.0 g of distilled water, as an emulsifier, was added to the above-mentioned prepolymer, and then the mixture was stirred with a homomixer for 1 minute to be emulsified. Immediately after it, an aqueous solution wherein 6.91 g of DETA and 5.70 g of IPDA were dissolved in 496.4 g of distilled water was added thereto, and then the mixture was stirred with the homomixer for 1 minute to perform chain-extending reaction. Subsequently, MEK was removed with a rotary evaporator to give a polyurethane emulsion (referred to as PU ①) whose solid content was 35% by weight.

[Reference Example 7] (Production of a polyurethane-based emulsion)

[0102] Into a three-neck flask were weight out 200.0 g of PHC2000, 100.0 g of PTMG1000, 105.1 g of MDI and 8.85 g of DMPA, and the mixture was stirred in the atmosphere of dry nitrogen at 90°C for 2 hours to react hydroxyl groups in the present system quantitatively. Thus, a prepolymer having an isocyanate terminal was obtained. To this prepolymer were added 219.1 g of MEK, and the mixture was homogeneously mixed. Thereafter, the temperature inside the flask was lowered to 40°C, and then 6.68 g of TEA were added thereto followed by stirring for 10 minutes. Next, an aqueous solution wherein 13.17 g of sodium polyoxyethylenetrisdecylether acetate (anionic emulsifier "ECT-3NEX", made by Japan Surfactant Company) were dissolved in 319.9 g of distilled water, as an emulsifier, was added to the above-mentioned prepolymer, and then the mixture was stirred with a homomixer for 1 minute to be emulsified. Immediately after it, an aqueous solution wherein 4.52 g of DETA and 11.20 g of IPDA were dissolved in 538.0 g of distilled water was added thereto, and then the mixture was stirred with the homomixer for 1 minute to perform chain-extending reaction. Subsequently, MEK was removed with a rotary evaporator to give a polyurethane emulsion (referred to as PU ②) whose solid content was 35% by weight.

[Reference Example 8] (Production of a polyurethane-based emulsion)

[0103] Into a three-neck flask were weight out 300.0 g of PCL2000, 70.53 g of TDI, and 10.06 g of DMPA, and the mixture was stirred in the atmosphere of dry nitrogen at 90°C for 2 hours to react hydroxyl groups in the present system quantitatively. Thus, a prepolymer having an isocyanate terminal was obtained. To this prepolymer were added 204.4 g of MEK, and the mixture was homogeneously mixed. Thereafter, the temperature inside the flask was lowered to 40°C and then 7.59 g of TEA were added thereto followed by stirring for 10 minutes. Next, an aqueous solution wherein 12.29 g of sodium lauryl sulfate were dissolved in 296.3 g of distilled water, as an emulsifier, was added to the above-mentioned prepolymer, and then the mixture was stirred with a homomixer for 1 minute to be emulsified. Immediately after it, an aqueous solution wherein 8.82 g of DETA and 2.57 g of EDA were dissolved in 521.2 g of distilled water was added thereto, and then the mixture was stirred with the homomixer for 1 minute to perform chain-extending reaction. Subsequently, MEK was removed with a rotary evaporator to give a polyurethane emulsion (referred to as PU ③) whose solid content was 35% by weight. [Reference Example 9] (Production of a polyurethane-based emulsion)

[0104] Into a three-neck flask were weight out 200.0 g of PHC2000, 100.0 g of PTMG1000, 80.91 g of IPDI and 7.38 g of DMPA, and the mixture was stirred in the atmosphere of dry nitrogen at 90°C for 2 hours to react hydroxyl groups in the present system quantitatively. Thus, a prepolymer having an isocyanate terminal was obtained. To this prepolymer were added 203.1 g of MEK, and the mixture was homogeneously mixed. Thereafter, the temperature inside the flask was lowered to 40°C, and then 5.57 g of TEA were added thereto followed by stirring for 10 minutes. Next, an aqueous solution wherein 12.21 g of sodium lauryl sulfate were dissolved in 298.5 g of distilled water, as an



emulsifier, was added to the above-mentioned prepolymer, and then the mixture was stirred with a homomixer for 1 minute to be emulsified. Immediately after it, an aqueous solution wherein 1.78 g of DETA and 13.23 g of IPDA were dissolved in 514.1 g of distilled water was added thereto, and then mixture was stirred with the homomixer for 1 minute to perform chain-extending reaction. Subsequently, MEK was removed with a rotary evaporator to give a polyurethane emulsion (referred to as PU ④) whose solid content was 35% by weight.

[Example 1] (Production of a composite resin emulsion and a leather-like sheet)

[0105] Into a flask with a cooling tube were weight out 240 g of PU ①, 0.020 g of ferrous sulfate heptahydrate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ), 0.294 g of potassium pyrophosphate, 0.451 g of Rongalite (bihydrate salt of sodium formaldehyde sulfoxylate), 0.020 g of disodium ethylenediamine tetraacetate (EDTA, 2Na) and 246 g of distilled water. The temperature of the mixture was raised to 40°C, and then the inside in the present system was sufficiently replaced by nitrogen. Next, into the flask were dropwise added a mixture (monomer ①) of 152.1 g of BA, 3.14 g of HDDA, 1.57 g of ALMA and 1.57 g of ECT-3NEX, and an emulsion (initiator ①) of 0.314 g of CHP, 0.314 g of ECT-3NEX and 15.0 g of distilled water through different dropping funnels over 4 hours. After the addition, the flask was kept at 40°C for 30 minutes. Thereafter, into the flask were dropwise added a mixture (monomer ②) of 38.4 g of MMA, 0.78 g of HDDA, 0.392 g of ECT-3NEX, and an emulsion (initiator ②) of 0.078 g of CHP, 0.078 g of ECT-3NEX and 3.0 g of distilled water through different dropping funnels over 1.5 hour. After the addition, the flask was kept at 50°C for 60 minutes to complete the polymerization. Thus, an emulsion whose solid content was 40% by weight was obtained. Four parts by weight of a nonionic surfactant ("Emulgen 109P", made by Kao Corp.) and 1 part of calcium chloride were blended with 100 parts by weight of the above-mentioned emulsion to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4.

[0106] The nonwoven fabric ① obtained in Reference Example 1 was immersed into the bath of the above-mentioned heat-sensible gelatinizing emulsion, to impregnate the nonwoven fabric ① with the emulsion. The nonwoven fabric ① was then taken out from the bath, squeezed with a press roll, and then immersed into a hot water bath of 90°C for 1 minute to solidify the heat-sensible gelatinizing emulsion. The nonwoven fabric ① was dried in a hot air drier of 130°C for 30 minutes to produce a sheet. Next, this sheet was immersed into toluene of 90°C and during the immersion squeezing treatment with a press roll was performed at 2 kg/cm<sup>2</sup> 5 times to dissolve and remove the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric, thereby giving a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fabric of 6-nylon and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 57% by weight of the nonwoven fabric after having been made into a microfibrillar form. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 4.

[Example 2]

[0107] In the same way as in Example 1, raw materials shown in Table 3 were used to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4. In the same way as in Example 1, the nonwoven fabric ② obtained in Reference Example 2 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion to produce a sheet. Next, the sheet was immersed into toluene of 90°C and during the immersion squeezing treatment with a press roll was performed at 2 kg/cm<sup>2</sup> 5 times to dissolve and remove the sea component (polyethylene) of the sea-island type composite spun fiber which made the nonwoven fabric, thereby giving a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fabric of polyethyleneterephthalate and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 52% by weight of the nonwoven fabric after having been made into a microfibrillar form. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 4.

[Example 3]

[0108] In the same way as in Example 1, raw materials shown in Table 3 were used to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4. The nonwoven fabric ③ obtained in Reference Example 3 was immersed into the bath of the heat-sensible gelatinizing emulsion to impregnate the nonwoven fabric ③ with this emulsion. The nonwoven fabric ③ was taken out from the bath, and squeezed with a press roll. Steam having a pressure of 1.5 kg/cm<sup>2</sup> was then sprayed on the whole of nonwo-



ven fabric ③ to solidify the heat-sensible gelatinizing emulsion, and was dried in a hot air dryer of 130°C for 30 minutes to produce a sheet. Next, the sheet was immersed into toluene of 90°C and during the immersion squeezing treatment with a press roll was performed at 2 kg/cm<sup>2</sup> 5 times to dissolve and remove the sea component (polystyrene) of the sea-island type composite spun fiber which made the nonwoven fabric, thereby giving a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fabric of polyethyleneterephthalate and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 61% by weight of the nonwoven fabric after having been made into a microfine fiber form. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 4.

[Example 4]

[0109] In the same way as in Example 1, raw materials shown in Table 3 were used to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4. To 100 parts of the above-mentioned heat-sensible gelatinizing emulsion was added 0.5 part of a substrate-moistening agent ("Polyflow-KL-260", made by TCS Company) as a penetrant, and then the nonwoven fabric ① obtained in Reference Example 1 was immersed into the bath of this heat-sensible gelatinizing emulsion to impregnate the nonwoven fabric ① with this emulsion. The nonwoven fabric ① was taken out from the bath, squeezed with a press roll and then heated in a hot air drier of 130°C for 30 minutes to solidify the emulsion and dry the nonwoven fabric ①. Thus, a sheet was obtained. Next, the same way as in Example 1 was performed to dissolve and remove the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric, thereby giving a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fabric of 6-nylon and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 59% by weight of the nonwoven fabric after having been made into a microfine fiber form. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 4.



Table 3

		Example				Comparative Example		
		1	2	3	4	1	2	3
Initial charging	PU emulsion	PU ① 240 g	PU ① 400 g	PU ② 560 g	PU ③ 240 g	PU ③ 240 g	PU ① 240 g	PU ① 240 g
	FeSO <sub>4</sub> 7H <sub>2</sub> O	0.020 g	0.014 g	0.008 g	0.020 g	0.020 g	0.020 g	0.020 g
	Potassium pyrophosphate	0.294 g	0.210 g	0.126 g	0.294 g	0.294 g	0.294 g	0.294 g
	Rongalite	0.451 g	0.322 g	0.193 g	0.451 g	0.451 g	0.451 g	0.451 g
	EDTA.2Na	0.020 g	0.014 g	0.008 g	0.020 g	0.020 g	0.020 g	0.020 g
	distilled water	246 g	143 g	43 g	252 g	244 g	244 g	246 g
Monomer ①	BA	152.1 g	119.7 g	40.3 g	163.9 g		192.1 g	152.1 g
	EHA			7.56 g	18.6 g			
	MMA					186.2 g		
	HDDA	3.14 g	6.30 g	2.52 g	1.86 g	9.80 g	3.92 g	3.14 g
	ALMA	1.57 g			1.86 g			1.57 g
	ECT-3NEX <sup>*1)</sup>	1.57 g	1.26 g	0.504 g	1.86 g	1.96 g	1.96 g	1.57 g
Initiator ①	CHP	0.314 g	0.252 g	0.101 g	0.186 g	0.392 g	0.392 g	0.314 g
	ECT-3NEX <sup>*1)</sup>	0.314 g	0.252 g	0.101 g	0.186 g	0.392 g	0.392 g	0.314 g
	Distilled water	15.0 g	15.0 g	10.0 g	10.0 g	20.0 g	20.0 g	15.0 g
Monomer ②	MMA	38.4 g	11.2 g	30.2 g	9.80 g	--	--	38.4 g
	BA			3.36 g				
	St		2.8 g			--	--	
	HDDA	0.78 g				--	--	0.78 g
	ECT-3NEX <sup>*1)</sup>	0.392 g	0.140 g	0.336 g	0.098 g	--	--	0.392 g
Initiator ②	CHP	0.078 g	0.028 g	0.067 g	0.018 g	--	--	0.078 g
	ECT-3NEX <sup>*1)</sup>	0.078 g	0.028 g	0.067 g	0.018 g	--	--	0.078 g
	Distilled water	3.0 g	2.0 g	3.0 g	2.0 g	--	--	3.0 g
Gelatinizing agent	Emulgen 109P	4 parts	4 parts	4 parts	4 parts	4 parts	4 parts	--
	CaCl <sub>2</sub>	1 part	1 part	1 part	1 part	1 part	1 part	--
Solid content (% by weight)		40	40	40	40	40	40	40

\*1): Anionic emulsifier

## [Comparative Example 1]

[0110] In the same way as in Example 1, only MMA was used as a monofunctional ethylenic unsaturated monomer, as shown in Table 3, to obtain an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4. In the same way as in Example 1, the nonwoven fabric ① obtained in Reference Example 1 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion. Thereafter, the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric was dissolved and removed to give a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fab-



ric of 6-nylon and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 58% by weight of the nonwoven fabric after having been made into a microfibrillar form. About this sheet, the elastic modulus at 90°C of the used emulsion was higher than the range defined in the present invention. Thus, this sheet had poor softness and was hard. Its adhesion weight of the resin, bending fatigue resistance, flexural rigidity and hand touch are shown in Table 4.

[Comparative Example 2]

[0111] In the same way as in Example 1, only BA was used as a monofunctional ethylenic unsaturated monomer, as shown in Table 3, to obtain an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4. In the same way as in Example 1, the nonwoven fabric ① obtained in Reference Example 1 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion. Thereafter, the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric was dissolved and removed to give a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fabric of 6-nylon and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 57% by weight of the nonwoven fabric after having been made into a microfibrillar form. About this sheet, the elastic modulus at 160°C of the used emulsion was lower than the range defined in the present invention. Thus, settling was caused in this sheet so that the sheet was like paper and was not dense as a whole. Its adhesion weight of the resin, bending fatigue resistance, flexural rigidity and hand touch are shown in Table 4.

[Comparative Example 3]

[0112] The same way as in Example 1 was performed except that Emulgen 109P and calcium chloride were not blended, to obtain an emulsion. This emulsion did not exhibit heat-sensible gelatinizing ability. The elastic moduli at 90°C and 160°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 4. In the same way as in Reference Example 1, the nonwoven fabric ① obtained in Reference Example 1 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion, so that the emulsion flowed out into the hot water bath and the bath was polluted. Next, in the same way as in Example 1, the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric was dissolved and removed to give a leather-like sheet wherein the composite resin was penetrated into the entangled nonwoven fabric of 6-nylon and was solidified. The adhesion weight of the composite resin in this leather-like sheet was 34% by weight of the nonwoven fabric after having been made into a microfibrillar form. Thus, settling was caused in this sheet so that the sheet was like paper and was not dense as a whole. Its adhesion weight of the resin, bending fatigue resistance, flexural rigidity and hand touch are shown in Table 4.



Table 4

	Example				Comparative Example		
	1	2	3	4	1	2	3
Heat-sensi- ble gelatiniz- ing temperature (°C)	52	54	49	51	50	54	>90
E' (90°C) *1)	$1.3 \times 10^8$	$4.8 \times 10^7$	$1.4 \times 10^8$	$2.5 \times 10^7$	$7.2 \times 10^8$	$8.8 \times 10^5$	$1.3 \times 10^8$
E' (160°C) *1)	$3.7 \times 10^7$	$2.9 \times 10^7$	$3.9 \times 10^7$	$1.6 \times 10^7$	$4.1 \times 10^7$	$3.8 \times 10^6$	$3.7 \times 10^7$
T $\alpha$ (°C)	-33	-37	-31	-38	5	-38	-33
Nonwoven fabric	Non-woven fabric ①	Non-woven fabric ②	Non-woven fabric ③	Non-woven fabric ①	Non-woven fabric ①	Non-woven fabric ①	Non-woven fabric ①
Adhesion weight of resin/fiber weight (% by weight)	57	52	61	59	58	57	34
Bending fatigue resistance (10000 times)	Good	Good	Good	Good	20	Good	Good
Flexural rigidity *2)	5.0	5.1	5.5	3.8	11.2	9.7	8.9
Hand touch	Good	Good	Good	Good	Bad	Bad	Bad

\*1) Unit: dyn/cm<sup>2</sup>\*2) Unit: gfcm<sup>2</sup>/cm

## [Example 5]

[0113] The nonwoven fabric ④ obtained in Reference Example 4 was immersed into the bath of the heat-sensible gelatinizing emulsion obtained in Example 1, to impregnate the nonwoven fabric ① with this emulsion. The nonwoven fabric ④ was then taken out from the bath, squeezed with a press roll, and then immersed into a hot water bath of 90°C for 1 minute to solidify the heat-sensible gelatinizing emulsion. The nonwoven fabric ④ was dried in a hot air drier of 130°C for 30 minutes to produce a sheet. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 6.

## [Example 6]

[0114] Into a flask with a cooling tube were weight out 480 g of PU ①, 0.011 g of ferrous sulfate heptahydrate (FeSO<sub>4</sub>·7H<sub>2</sub>O), 0.168 g of potassium pyrophosphate, 0.258 g of Rongalite, 0.011 g of EDTA·2Na and 98 g of distilled water. The temperature of the mixture was raised to 40°C and then the inside in the present system was replaced by nitrogen. Next, into the flask were dropwise added a mixture (monomer ①) of 95.2 g of BA, 11.2 g of MMA, 5.60 g of HDDA and 1.12 g of ECT-3NEX, and an emulsion (initiator ①) of 0.168 g of CHP, 0.168 g of ECT-3NEX and 10.0 g of distilled water through different dropping funnels over 4 hours. After the addition, the flask was kept at 50°C for 60 minutes to complete the polymerization. Thus, an emulsion whose solid content was 40% by weight was obtained. Four parts by weight of "Emulgen 109P" and 1 part of calcium chloride were blended with 100 parts by weight of the above-mentioned emulsion to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing tem-



perature of this emulsion, and elastic modulus at 90°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 6.

[0115] In the same way as in Example 5, the nonwoven fabric ④ obtained in Reference Example 4 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion, to produce a sheet. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 4.

[Example 7]

[0116] In the same way as in Example 1, raw materials shown in Table 5 were used to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic modulus at 90°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 6. The nonwoven fabric ⑤ obtained in Reference Example 5 was immersed into the bath of the above-mentioned heat-sensible gelatinizing emulsion to impregnate the nonwoven fabric ⑤ with this emulsion. The nonwoven fabric ⑤ was taken out from the bath, and squeezed with a press roll. Steam having a pressure of 1.5 kg/cm<sup>2</sup> was then sprayed on the whole of the nonwoven fabric ⑤ to solidify the heat-sensible gelatinizing emulsion, and was dried in a hot air dryer of 130°C for 30 minutes to produce a sheet. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 6.

[Example 8]

[0117] In the same way as in Example 1, raw materials shown in Table 5 were used to give an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic modulus at 90°C and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 6. A commercially available polyester woven/knitted fabric (thickness: 0.85 mm, and apparent density: 0.35 g/cm<sup>3</sup>) which was not treated with a softening water-repellent was immersed into the bath of the above-mentioned heat-sensible gelatinizing emulsion to impregnate the fabric with this emulsion. The fabric was taken out from the bath, and squeezed with a press roll. Next, the fabric was heated in a hot air dryer of 130°C for 30 minutes to solidify and dry the emulsion, thereby producing a sheet. This sheet was a sheet, like natural leather, which had softness and fulfillment feeling and which was excellent in hand touch and endurance, as shown in Table 6.

[Comparative Example 4]

[0118] In the same way as in Example 6, only MMA was used as a monofunctional ethylenic unsaturated monomer, as shown in Table 5, to obtain an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic modulus at 90°C and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 6. In the same way as in Example 1, the nonwoven fabric ④ obtained in Reference Example 4 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion to produce a sheet. About this sheet, the elastic modulus at 90°C of the used emulsion was higher than the range defined in the present invention. Thus, this sheet had poor softness and was hard.

[Comparative Example 5]

[0119] In the same way as in Example 6, only BA was used as a monofunctional ethylenic unsaturated monomer, as shown in Table 5, to obtain an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic modulus at 90°C and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 6. In the same way as in Example 1, the nonwoven fabric ④ obtained in Reference Example 4 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion to produce a sheet. About this sheet, the elastic modulus at 90°C of the used emulsion was lower than the range defined in the present invention. Thus, this sheet had good softness but poor fulfillment feeling.

[Comparative Example 6]

[0120] The same way as in Example 1 was performed except that "Emulgen 109P" and calcium chloride were not blended, to obtain an emulsion. This emulsion did not exhibit heat-sensible gelatinizing ability. The elastic modulus at 90°C, and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion are as shown in Table 6. In the same way as in Example 5, the nonwoven fabric ④ obtained in Reference Example 4 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion, so that the emulsion flowed out into the hot water bath and the bath was pol-



luted. This sheet locally had hard portions, and portions that were not dense and was like nonwoven fabric.

Table 5

		Example				Comparative Example		
		5	6	7	8	4	5	6
Initial charging	PU emulsion	PU ① 240 g	PU ① 480 g	PU ④ 480 g	PU ③ 240 g	PU ① 240 g	PU ④ 240 g	PU ① 240 g
	FeSO <sub>4</sub> 7H <sub>2</sub> O	0.020 g	0.011 g	0.011 g	0.020 g	0.020 g	0.020 g	0.020 g
	Potassium pyrophosphate	0.294 g	0.168 g	0.168 g	0.294 g	0.294 g	0.294 g	0.294 g
	Rongalite	0.451 g	0.258 g	0.258 g	0.451 g	0.451 g	0.451 g	0.451 g
	EDTA.2Na	0.020 g	0.011 g	0.011 g	0.020 g	0.020 g	0.020 g	0.020 g
	distilled water	246 g	98 g	95 g	252 g	244 g	244 g	246 g
Monomer ①	BA	152.1 g	95.2 g	74.5 g	163.9 g		186.2 g	152.1 g
	EHA				18.6 g			
	MMA		11.2 g			186.2 g		
	HDDA	3.14 g	5.60 g	2.35 g	1.86 g	9.80 g	9.80 g	3.14 g
	ALMA	1.57 g		1.57 g	1.86 g			1.57 g
	ECT-3NEX *1)	1.57 g	1.12 g	0.784 g	1.86 g	1.96 g	1.96 g	1.57 g
Initiator ①	CHP	0.314 g	0.168 g	0.157 g	0.186 g	0.392 g	0.392 g	0.314 g
	ECT-3NEX *1)	0.314 g	0.168 g	0.157 g	0.186 g	0.392 g	0.392 g	0.314 g
	Distilled water	15.0 g	10.0 g	10.0 g	10.0 g	20.0 g	20.0 g	15.0 g
Monomer ②	MMA	38.4 g	--	26.2 g	9.80 g	--	--	38.4 g
	St		--	6.7 g		--	--	
	HDDA	0.78 g	--	0.67 g		--	--	0.78 g
	ECT-3NEX *1)	0.392 g	--	0.336 g	0.098 g	--	--	0.392 g
Initiator ②	CHP	0.078 g	--	0.067 g	0.018 g	--	--	0.078 g
	ECT-3NEX *1)	0.078 g	--	0.067 g	0.018 g	--	--	0.078 g
	Distilled water	3.0 g	--	3.0 g	2.0 g	--	--	3.0 g
Gelatizing agent	Emulgen 109P	4 parts	4 parts	4 parts	4 parts	4 parts	4 parts	--
	CaCl <sub>2</sub>	1 part	1 part	1 part	1 part	1 part	1 part	--
Solid content (% by weight)		40	40	40	40	40	40	40

\*1): Anionic emulsifier



Table 6

	Example				Comparative Example		
	5	6	7	8	4	5	6
Heat-sensible gelatinizing temperature (°C)	52	51	49	51	50	54	>90
E (90°C) * <sup>1)</sup>	$1.3 \times 10^8$	$1.9 \times 10^7$	$9.4 \times 10^7$	$2.5 \times 10^7$	$7.2 \times 10^8$	$6.0 \times 10^6$	$1.3 \times 10^8$
T α (°C)	-33	-32	-30	-38	5	-33	-33
Adhesion weight of resin/fiber weight (% by weigh)	66	64	30	37	67	65	31
Bending resistance (100,000 times)	Good	Good	Good	Good	10	Good	Good
Flexural rigidity * <sup>2)</sup>	5.1	4.0	5.5	4.8	11.8	2.9	7.1
Hand touch	Good	Good	Good	Good	Bad	Bad	Bad

\*1) Unit: dyn/cm<sup>2</sup>\*2) Unit: g/cm<sup>2</sup>/cm

## [Reference Example 10] (Production of an acrylic polymer emulsion)

[0121] Into a flask with a cooling tube were weight out 0.420 g of sodium di(2-ethylhexyl) sulfosuccinate and 520 g of distilled water. The temperature of the mixture was raised to 80°C, and then the inside in the present system was replaced by nitrogen. Next, 0.378 g of potassium persulfate was added thereto. From 5 minutes after it, into the flask were dropwise added a mixture of 239.4 g of BA, 7.56 g of HDDA and 5.04 g of ALMA and 1.01 g of sodium di(2-ethylhexyl)sulfosuccinate through a dropping funnel over 3 hours. After the addition, the flask was kept at 80°C for 1 hour. Thereafter, 0.028 g of potassium persulfate was added thereto. Thereafter, 26.6 g of MMA, 0.840 g of methacrylic acid, 0.560 g of HDDA and 0.112 g of sodium di(2-ethylhexyl)sulfosuccinate through the dropping funnel over 1 hour. After the addition, the flask was kept at 80°C for 1 hour to complete the polymerization. Thus, an emulsion whose solid content was 35% by weight was obtained. The emulsion is referred to as acryl emulsion ① hereinafter.)

## [Comparative Example 7] (Acrylic/PU blend type)

[0122] Into a mixture of 50 parts by weight of PU ① obtained in Reference Example 6 and the acryl emulsion ① obtained in Reference Example 10 were added 4 parts by weight of a nonionic surfactant ("Emulgen 109P" made by Kao Corp.) and 1 part by weight of calcium chloride, to obtain an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and elastic moduli at 90°C and 160°C and α dispersion temperature (T α) of a film obtained by drying the emulsion were 50°C,  $5.9 \times 10^7$  dyn/cm<sup>2</sup>,  $1.3 \times 10^7$  dyn/cm<sup>2</sup>, and -41°C, respectively.

[0123] In the same way as in Example 1, the nonwoven fabric ① obtained in Reference Example 1 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion. Thereafter, the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric was dissolved and removed to give a leather-like sheet wherein the mixture of the polyurethane and the acrylic polymer was penetrated into the microfibrillar bundle entangled nonwoven fabric of 6-nylon and was solidified. The adhesion weight of the mixture of the polyurethane and the acrylic polymer in this leather-like sheet was 45% by weight of the nonwoven fabric after having been made into a microfibrillar form. Settling was caused in this sheet so that the sheet was like paper and was not dense as a whole. Its bending fatigue resistance, flexural rigidity and hand touch were good, 9.9 g/cm<sup>2</sup>/cm, and bad, respectively.

## [Comparative Example 8] (Acrylic type alone)

[0124] Into 100 parts by weight of acryl emulsion ① obtained in Reference Example 10 were added 4 parts by weight of a nonionic surfactant ("Emulgen 109P" made by Kao Corp.) and 1 part by weight of calcium chloride, to obtain an emulsion having heat-sensible gelatinizing ability. The heat-sensible gelatinizing temperature of this emulsion, and



elastic modulus at 90°C and  $\alpha$  dispersion temperature ( $T_\alpha$ ) of a film obtained by drying the emulsion were 48°C,  $3.4 \times 10^7$  dyn/cm<sup>2</sup> and -43°C, respectively. The elastic modulus at 160°C was unable to be measured since the film was torn.

[0125] In the same way as in Example 1, the nonwoven fabric ① obtained in Reference Example 1 was impregnated with the above-mentioned heat-sensible gelatinizing emulsion. Thereafter, the sea component (polyethylene) of the sea-island type blend spun fiber which made the nonwoven fabric was dissolved and removed to give a leather-like sheet wherein the acrylic polymer was penetrated into the microfibrillar bundle entangled nonwoven fabric of 6-nylon and was solidified. As a result, in the step of converting the fiber into a microfibrillar bundle, the acrylic polymer was eluted out with polyethylene. The adhesion weight of the acrylic polymer in this leather-like sheet was 18% by weight of the nonwoven fabric after having been made into a microfibrillar fiber form. This sheet had poor softness and was hard. Its bending fatigue resistance, flexural rigidity and hand touch were 300,000, 11.8 g/cm<sup>2</sup>/cm, and bad, respectively.

[0126] According to the process of the present invention, it is possible to produce, at a low price, a leather-like sheet having hand touch like natural leather and having still more improved softness and fulfillment feeling than the sheet based on supply of any conventional emulsion type resin. In the case that the fibrous substrate especially comprises any microfibrillar fiber, it is possible to produce a leather-like sheet which has more satisfactory softness and fulfillment feeling and has hand touch like natural leather by the use of the microfibrillar fiber substrate and the composite resin emulsion.

### Claims

1. A process for producing a leather-like sheet, comprising the step of impregnating a fibrous substrate with a composite resin emulsion having the following requirements (i)-(iv), solidifying the emulsion, and then performing the step (v):
  - (i) the requirement that the composite resin emulsion has heat-sensible gelatinizing ability,
  - (ii) the requirement that a film of 100  $\mu$ m in thickness, obtained by drying the composite resin emulsion at 50°C has an elastic modulus at 90°C of  $5.0 \times 10^8$  dyn/cm<sup>2</sup> or less, and in the case that a fiber which makes the fibrous substrate is not any microfibrillar fiber-forming fiber, the elastic modulus is  $1.0 \times 10^7$  dyn/cm<sup>2</sup> or more,
  - (iii) the requirement that in the case that the fiber which makes the fibrous substrate is a microfibrillar fiber-forming fiber, the film of 100  $\mu$ m in thickness, obtained by drying the composite resin emulsion at 50°C, has an elastic modulus at 160°C of  $5.0 \times 10^6$  dyn/cm<sup>2</sup> or more,
  - (iv) the requirement that the composite resin emulsion is an emulsion that can be obtained by emulsion-polymerizing an ethylenically unsaturated monomer (B) in the presence of a polyurethane-based emulsion (A) in the manner that a weight ratio of polyurethane in the component (A) to the component (B) is from 90/10 to 10/90, and
  - (v) in the case that the fibrous substrate is the microfibrillar fiber-forming fiber, subsequently converting the microfibrillar fiber-forming fiber into a microfibrillar fiber bundle.
2. The process for producing a leather-like sheet according to claim 1, wherein the film of 100  $\mu$ m in thickness, obtained by drying the composite resin emulsion at 50°C has  $\alpha$  dispersion temperature of -10°C or lower.
3. The process for producing a leather-like sheet according to claim 1 or 2, wherein as the fibrous substrate there is used a fibrous substrate to which a fiber treating agent having a function of blocking adhesion between the fiber and the composite resin is beforehand added.
4. The process for producing a leather-like sheet according to claim 3, wherein the fiber treating agent having the function of blocking adhesion between the fiber and the composite resin is a softening water-repellent comprising a mixture of dimethylpolysiloxane and methylhydrogenpolysiloxane.
5. The process for producing a leather-like sheet according to any one of claims 1 to 4, wherein the composite resin emulsion has a heat-sensible gelatinizing temperature of 30 to 70°C, and the fibrous substrate is impregnated with the composite resin emulsion and subsequently the composite resin emulsion is solidified at a temperature at least 10°C higher than the heat-sensible gelatinizing temperature.
6. The process for producing a leather-like sheet according to any one of claims 1 to 5, wherein the fibrous substrate is a nonwoven fabric that is produced by using a shrinkable polyethyleneterephthalate fiber as at least one component and that has an apparent density of 0.25 to 0.50 g/cm<sup>3</sup>.
7. The process for producing a leather-like sheet according to any one of claims 1 to 6, wherein in the case that the



fibrous substrate comprises the microfibrillar fiber-forming fiber, the polyurethane-based emulsion (A) is an emulsion of a polyurethane produced by using an aromatic isocyanate compound.

8. The process for producing a leather-like sheet according to any one of claims 1 to 7, wherein in the case that the fibrous substrate comprises the microfibrillar fiber-forming fiber, the ethylenically unsaturated monomer (B) comprises 90-99.9% by weight of a monofunctional ethylenic unsaturated monomer (B1) made mainly of a derivative of (meth)acrylic acid, and 10-0.1% by weight of a polyfunctional ethylenic unsaturated monomer (B2).
9. The process for producing a leather-like sheet according to any one of claims 1 to 8, which is a process comprising the step of impregnating the fibrous substrate comprising the microfibrillar fiber-forming fiber with the composite resin emulsion satisfying the requirements (i)-(iv), solidifying the emulsion, and converting the microfibrillar fiber-forming fiber into a microfibrillar fiber bundle, wherein the microfibrillar fiber-forming fiber is a sea-island type composite spun fiber and/or a sea-island type blend spun fiber comprising two or more polymers, and the fibrous substrate comprising the above-mentioned spun fiber is impregnated with the composite resin emulsion, the emulsion is solidified and subsequently a sea component of the sea-island type composite spun fiber and/or the sea-island type blend spun fiber is removed to convert the above-mentioned spun fiber into a microfibrillar fiber bundle.
10. The process for producing a leather-like sheet according to claim 9, wherein the sea-island type composite spun fiber and/or the sea-island type blend spun fiber have/has, as their/its sea component, polyethylene and/or polystyrene and have/has, as their/its island component, polyester and/or polyamide, and the fibrous substrate is impregnated with the composite resin emulsion, the emulsion is solidified, and subsequently the sea component of the sea-island type composite spun fiber and/or the sea-island type blend spun fiber is removed to convert the above-mentioned spun fiber into a microfibrillar fiber bundle.
11. A leather-like sheet obtainable by the process according to any one of claims 1-10.
12. A process for producing a composite resin emulsion, comprising emulsion-polymerizing an ethylenically unsaturated monomer (B) in the presence of a polyurethane-based emulsion (A), wherein a polyurethane-based emulsion satisfying the following requirements ①-③ is used as the polyurethane-based emulsion (A):
  - ① the requirement that the polyurethane-based emulsion is a polyurethane-based emulsion prepared by reacting an isocyanate-terminal prepolymer with a chain extender in the presence of a surfactant in an aqueous solution,
  - ② the requirement that the polyurethane-based emulsion is a polyurethane-based emulsion having, in its polyurethane skeleton, 5 to 25 mmol of neutralized carboxylic groups and/or sulfonic group per 100 g of the polyurethane, and
  - ③ the requirement that the polyurethane-based emulsion is a polyurethane-based emulsion having from 0.5 to 6 g of the surfactant per 100 g of the polyurethane.
13. The process according to claim 12, which is a process wherein an acrylic acid derivative-based monomer is first emulsion-polymerized and then a methacrylic acid-based derivative and/or an aromatic vinyl monomer are/is polymerized, the weight ratio of the acrylic acid derivative-based monomer to the methacrylic acid-based derivative and/or the aromatic vinyl monomer being from 50/50 to 99/1.